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Final Report

Feasibility Study for Cree and Schockopee Lakes

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EXECUTIVE SUMMARY

International Science & Technology, Inc. (IS&T) has provided technical services to the Cree Lake Association in conducting a feasibility study of the restoration of Cree and Schockopee Lakes. Cree Lake, a glacially-formed water body, located in Noble County, Indiana, has recently experienced accelerated loss of depth and severe plant growth problems in the canal system located along the lake's southeastern shore. Schockopee Lake, also glacially-formed, is situated directly upstream from Cree Lake and exerts considerable influence on the quality of the Cree system. In the 1970's, the Indiana Department of Environmental Management (IDEM) placed both lakes in its Class Two category of intermediate-quality lakes. The water bodies in this class are known to be adversely impacted by human activities and are moving slowly toward moderate to advanced stages of eutrophication. The feasibility study conducted by IS&T was funded through the Indiana Lake Enhancement Program (LEP).

The objectives of the feasibility study, were three-fold:

- Assess the current condition of the lake systems and establish a baseline against which future changes can be measured.
- Identify potential threats to the well-being of the systems, both in the lakes and in the watersheds.
- Recommend lake and/or watershed management practices that minimize such threats.

In pursuit of these goals, IS&T implemented a four part program. First, all relevant background information (e.g., resource maps, soil manuals) was gathered and reviewed to understand the physical setting and history of both lakes. Second, lake surveys were conducted to collect data on water quality, sediment quality, phytoplankton (i.e., algae) abundance, and aquatic macrophyte (i.e., non-algal vegetation) distribution. Third, watershed surveys were completed to identify upland activities resulting in excessive soil erosion and sediment/nutrient transport to the lakes. Finally, recommendations targeted toward improving the quality of both lakes were developed.

Based on the results of the watershed analyses, lake and tributary sampling, and visual observations, Cree and Schockopee Lakes appear to be adversely impacted in the following ways:

- The canal system in Cree Lake is experiencing advanced stages of eutrophication, as evidenced in the abundance of algae and macrophytes. The loss of depth in this area may be attributed largely to high levels of plant productivity that lead to increased sloughing and settling of biomass materials (i.e., algal cells and macrophyte tissue). The confined nature of the canals further exacerbates the problem because soluble plant nutrients are not readily mixed with the larger volumes of water available in the main body of the lake. Particulate plant nutrients entering the system via the small tributary leading from Schockopee are also trapped in the confinement.

- Primary sources of nutrients in the canal system include: (1) septic systems situated in the poorly drained soils along the canal shores; (2) recycling from the highly organic sediments on the canal bottom; (3) agricultural runoff entering the system through the tributary from Schockopee Lake; and (4) residential runoff from the lawns and gardens located along the system.

- The main body of Cree Lake appears to be relatively healthy in comparison with the canal system. The lake is, however, experiencing some problems with increased nutrient loading from septic systems and probably from lawn runoff along the shore. It appears that the canal system has protected the main body by acting as a sediment/nutrient trap, providing some measure of passive physical water treatment before pollutants enter the lake. If measures are not taken to restore the quality of the canals, it is anticipated that more pronounced effects will be observed in the lake as the resource degrades further.

- Schockopee Lake is influenced to a great extent by runoff from the predominantly agricultural watershed. Large amounts of sediments and nutrients enter Schockopee via the tributary that empties into the southeastern end of the lake. In addition, the water body probably receives some nutrients from septic systems near the lake. If runoff and nutrient loading continue in their current state, trophic conditions in Schockopee may be expected to deteriorate in the future.

- Nutrient loading from the atmosphere may be significant in both lakes but management techniques are not readily available for reducing such input.

Approaches to restoring the quality of both lakes were presented by IS&T. Options focus on both upland and in-lake measures and include the following:

- The Cree Lake Association, and other residents in the watershed should become familiar with agricultural best management practices (BMPs) for controlling sediment and nutrient export to surface water bodies. The Association should work with the local SCS District Conservationist's office, the Soil and Water Conservationist Office, and the Indiana Department of Natural Resources (IDNR) to encourage area farmers to install appropriate BMPs in locations deemed critical for preserving the quality of the lake resource. The agencies are responsible for coordinating the placement of

BMPs with farmers, providing free advice to landowners on appropriate strategies and designs, supervising the implementation of BMPs, and approving and providing cost-share programs (i.e., the "T by 2000" cropland erosion control cost-share program).

- Homeowners along the main body and canal system of Cree Lake should investigate alternatives to the current septic system arrangement. Given the prohibitive cost of constructing comprehensive waste water treatment facilities, replacement of septic systems with treatment systems that do not use drain fields would be most desirable. A suggested option is the installation of holding tanks to serve one or more residences so that septic inputs can be pumped out and removed by a septic maintenance company on a routine basis (e.g., monthly).

- In order to restore the health of the resource and to preserve property values associated with the water body, the Cree Lake Association should initiate a design study for the removal of the organic sediments in the Cree Lake canal system. A design study should furnish detailed engineering specifications and time tables for all on-site work to be done. The culmination of a design study is the preparation of bid-ready packages so that an appropriate contractor can be identified and hired via a cost-effective, competitive process.

It must be noted that in-lake restoration strategies (e.g., dredging) will only provide short-term relief of the symptoms associated with eutrophication. Effective land treatment measures (i.e., BMPs) must be established in the watershed and lakeside septic problems must be addressed before long-term improvements in lake quality can be expected. If the supply of nutrients and sediments is not reduced, the lake will return to its present condition (and possibly degrade further) regardless of any in-lake measures taken.

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SECTION 1. INTRODUCTION

International Science & Technology, Inc. (IS&T) has provided technical services and assistance to the Cree Lake Association in conducting a feasibility study on the restoration of Cree and Schockopee Lakes. The work was performed under provisions of the "T by 2000" Lake Enhancement Program (LEP) administered by the State Division of Soil Conservation, Indiana Department of Natural Resources. The LEP was established to ensure the continued viability of Indiana's public-access lakes by (1) controlling sediment and nutrient inflows, and (2) when appropriate, implementing remedial actions to forestall or reverse the impacts of such inflows. Feasibility studies funded through the LEP are intended to document the potential need and scope of future lake enhancement actions.

1.1 CREE AND SCHOCKOPEE LAKES

This investigation focused on both Cree and Schockopee Lakes. Cree Lake is the primary water body of concern because it is beginning to exhibit a decline in water quality. The principle justification for including Schockopee Lake in the investigation is its critical position in the Cree Lake drainage basin. Because it is located directly upstream, Schockopee Lake has a significant and inevitable impact on the trophic status of Cree Lake.

1.1.1 Cree Lake

Cree Lake is located in Noble County, Indiana near the northeastern corner of the state (Figure 1-1). The approximate center of the water body lies at 85°16'32" West longitude and 41°30'24" North latitude (Figure 1-1). The lake has a surface area of 58 acres (23.5 ha), a mean depth of 15.7 feet (4.8 m), and maximum depth of 27 feet (8.2 m). The shores of the lake are almost completely developed with approximately 100 homes and summer cottages. The remainder of the 3,490 acre (1,412 ha) watershed is predominantly forested and agricultural. Approximately 20 years ago, a series of canals was dug on the southeastern side of the lake. The shores of the canals are also extensively developed. Most of the homeowners in this area have installed seawalls to stabilize the banks of their property.

A natural, glacially-formed water body, Cree Lake is used for swimming and fishing by local residents and the public. There is a public access boat ramp on the western shore of the lake, along State Route 3.

In the mid-1970's the Indiana Department of Environmental Management (IDEM) analyzed the quality of Cree Lake and assigned an eutrophication index (EI) number of 39, placing it in the Class Two category of intermediate quality, intermediate level eutrophic lakes (IDEM, 1986). Water bodies in this class are characteristically productive with slowly changing trophic conditions and are known to be impacted by human activities. The EI value was based, in part, on a total phosphorus (TP) concentration of 0.07 mg/l and a Secchi disc transparency of 5.3 ft. (1.6 m).

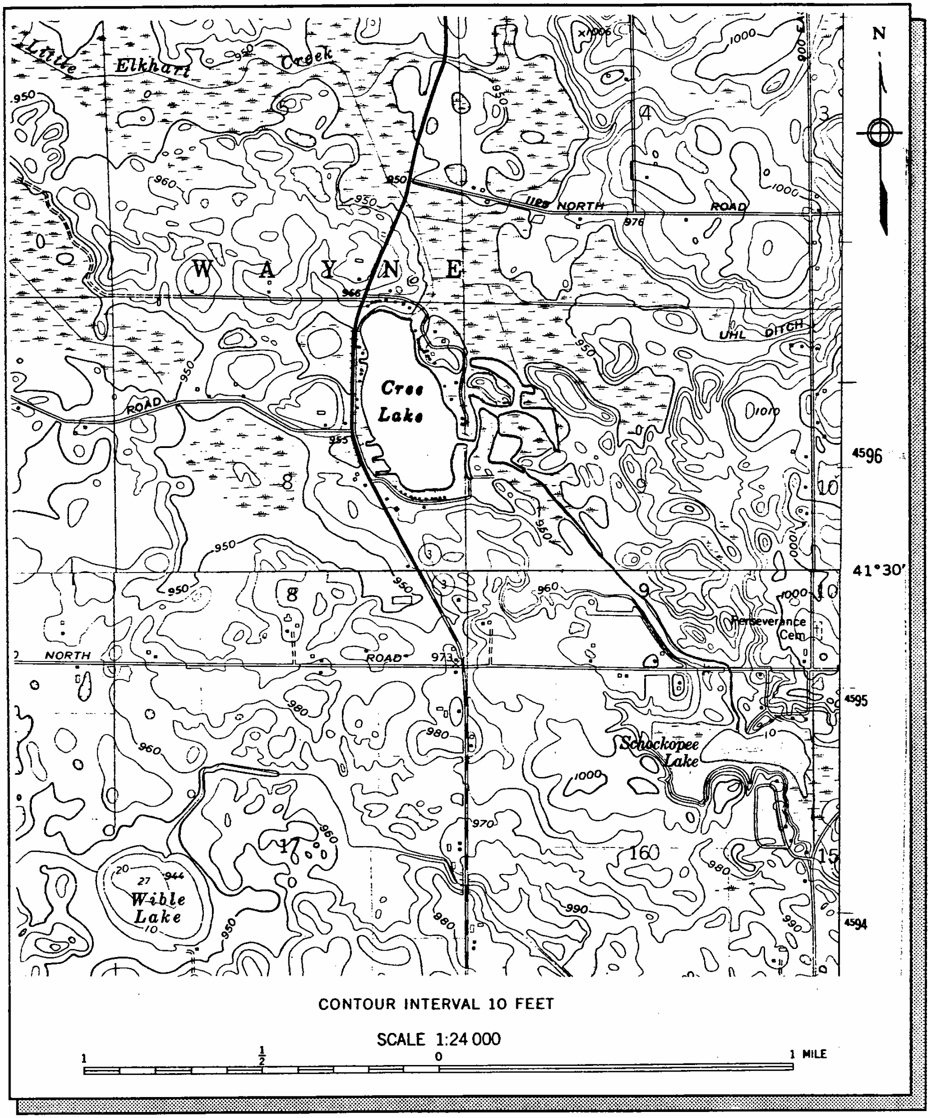

FIGURE 1-1. **Portion of the U.S. Geological Survey (USGS) Kendallville and Wolcottville quadrangles showing the locations of Cree and Schockopee Lakes.**

1.1.2 Schockopee Lake

Schockopee Lake is centrally located in the Cree Lake watershed at 85°15'15" West longitude and 41°29'35" North latitude (Figure 1-1). The 2,826 acre (1,144 ha) portion of the Cree/Schockopee catchment that drains directly into Schockopee Lake is predominantly agricultural in nature. The water body has a surface area of 21 acres (8.5 ha), a mean depth of 13.3 feet (4.1 m), and a maximum depth of 26 feet (7.9 M). An analysis of the lake by IDEM in 1986 reported a TP concentration of 0.04 mg/l and a Secchi disc transparency of 5 ft. (1.5 m). The lake was assigned an eutrophication index number of 30, placing it in the Class Two trophic category, the same classification as Cree Lake.

1.2 NATURE OF THE PROBLEM

Although the current status of Cree Lake can be described as only moderately eutrophic, there has been recent evidence of accelerated sediment accumulation. In particular, there has been significant loss of depth in the canal system located adjacent to the southeastern portion of the lake. The embayment in this area has developed extensive shoals and has lost approximately 5 feet (1.5 m) of depth. This loss has been accompanied by an increase in the occurrence of noxious aquatic plants, including *Cerataphyllum* sp. and *Lemna* sp. These plants also appear to be encroaching into the main body of the lake.

Prior to this feasibility study, sedimentation problems appeared to be related to loading from the agricultural sub-basin associated with the southeastern inlet stream. The observed sediment accumulation has severely impaired the recreational value of this portion of the lake. The problem is expected to expand to the rest of the lake system if mitigative measures are not taken both in the lake and in the watershed.

1.3 STUDY OBJECTIVES

In conducting the feasibility study on Cree and Schockopee Lakes, IS&T established the following objectives:

- Assess the current conditions of Cree and Schockopee Lakes and establish a baseline against which future changes can be measured.

- Identify sources of excessive sediment loading to the lakes.

- Recommend lake and/or watershed management practices that minimize such loading.

In pursuit of these objectives, IS&T implemented a four-part program. First, relevant background information (e.g., resource maps, soil manuals, fisheries studies) was gathered and reviewed to understand the physical setting of the lakes. Second, a lake survey was conducted to collect data on water quality, sediment quality, phytoplankton abundance, and aquatic macrophyte distribution. Third, a watershed survey was completed to identify all current watershed activities that are resulting in excessive soil erosion and sediment transport to the lakes. Finally, mitigative technologies were identified to address the observed problems. The mitigative alternatives include watershed land use and treatment strategies as targeted by the "T by 2000" Indiana Lake Enhancement Program, as well as in-lake measures.

SECTION 2. METHODS

This section of the report provides a description of the methods used to conduct the Cree and Schockopee Lakes feasibility study. Data collection efforts for the project were divided among three sub-tasks: (1) a literature survey; (2) a lake survey; and (3) a watershed survey. These sub-tasks are described below.

2.1 LITERATURE SURVEY

A survey of existing information was performed to identify and obtain all historical water quality, hydrologic, and land use data relevant to Cree and Schockopee Lakes. Contacted agencies included:

- Noble County Public Library
- Noble County Health Department
- Noble County Surveyor's Office
- Indiana Department of Environmental Management
- Indiana Department of Natural Resources
- U.S. Soil Conservation Service (Noble County).

Water quality data were requested from the Noble County Health Department and the Indiana Department of Environmental Management. Although all types of water quality information were sought, parameters of specific interest included: nutrients, Secchi disk transparency, chlorophyll-a, total solids, fecal coliform, and dissolved oxygen. Biological data (e.g., species composition, abundance) were also sought.

Climatic, hydrologic, and physiographic information was obtained through the Noble County Surveyor's Office, the U.S. Soil Conservation Service (SCS), the U.S. Agricultural Stabilization and Conservation Service (ASCS), the U.S. Geological Survey (USGS), and the National Oceanic and Atmospheric Administration (NOAA). Data included:

- Aerial photographs
- Topographic maps
- Soil surveys
- Erodible soil maps
- Agricultural practice reports
- Lake bathymetric maps
- Wetland reports
- Precipitation chemistry reports.

Because USGS land use maps were not available, aerial photographs, topographic maps, and ground surveys were combined to delineate land use in the watershed (Section 2.3.4).

Information on human populations and state listed species was identified and obtained. News clippings and other reports were collected to provide historical perspective on activities at Cree and Schockopee Lakes.

2.2 LAKE SURVEY

In order to provide information required for a detailed assessment of the current conditions in Cree and Schockopee Lakes, a field survey of the lakes was conducted on 13-17 July 1989. Components of the survey included:

- In-situ water quality measurements
- Chemical water quality measurements
- Biological water quality measurements
- Lake sediment core analyses
- Aquatic macrophyte mapping
- Bathymetric mapping.

The locations of sample sites are presented in Figures 2-1, 2-2, and 2-3.

2.2.1 In-situ Measurements

In-situ water quality parameters were sampled in the deepest area of each lake at stations $CL_{(WQ)}$ and $SL_{(WQ)}$. Measurements of pH, dissolved oxygen (DO), temperature, and conductivity were made at 2 foot (0.6 m) intervals from the lake surface to immediately above the sediment surface using a Hydrolab Surveyor II (Hydrolab Corp., Austin, TX). No measurements were made in Cree Lake at the 2 foot depth. Light transmission at a depth of 3 feet (0.9 m) was recorded using a Martek Model XMS (Martek Corporation, Irvine, CA) transmissometer. The transmissometer was calibrated in sunlight (i.e., 100 percent transmission) just above the lake surface at each sampling site. Secchi disk transparency was also measured. The data were used to characterize mid-summer conditions in the lake and to construct an index of trophic status.

2.2.2 Chemical Measurements

Water samples were collected with a 6.6 quart (6.2 l) Van Dorn sampler (Wildco Supply Co., Saginaw, MI) at stations $CL_{(WQ)}$ and $SL_{(WQ)}$. Samples were collected at three depths in Cree Lake: (1) just below the lake surface; (2) at the mid-depth of 13 feet (4.0 m); and (3) one foot above the lake bottom, at 26 feet (7.9 m). Similarly, samples collected from Schockopee Lake were taken from three depths: (1) just below the lake surface; (2) at the mid-depth of 12 feet (3.7 m); and (3) one foot above the lake bottom, at 24 feet (7.3 m). Samples were labeled and placed in acid-washed one liter Cubitainer containers (Hedwin Corp., Baltimore, MD). Separate fecal coliform aliquots from each depth were placed in six ounce Whirl-Pak bags (Nasco, Inc., Ft. Atkinson, WI). All samples were stored

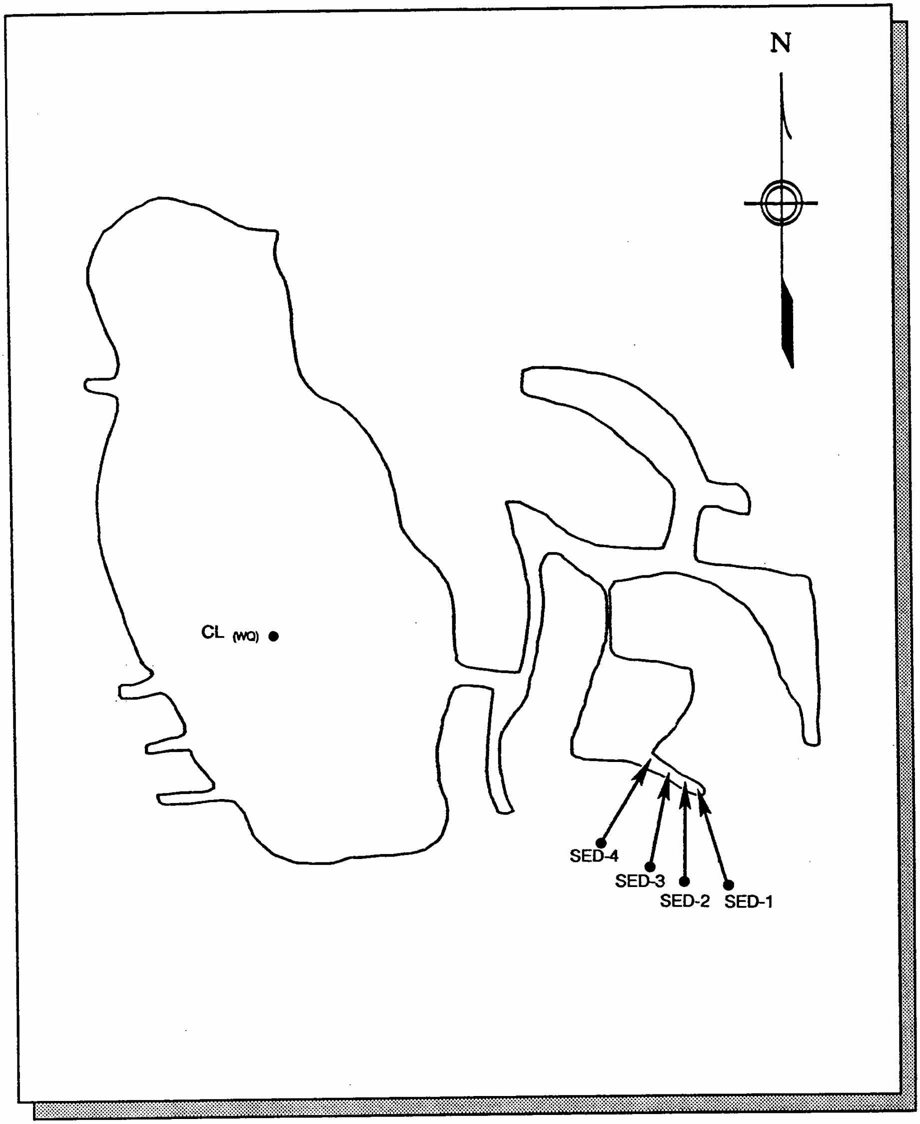

FIGURE 2-1. Locations of in-lake (CL) and sediment (SED) sampling stations on Cree Lake.

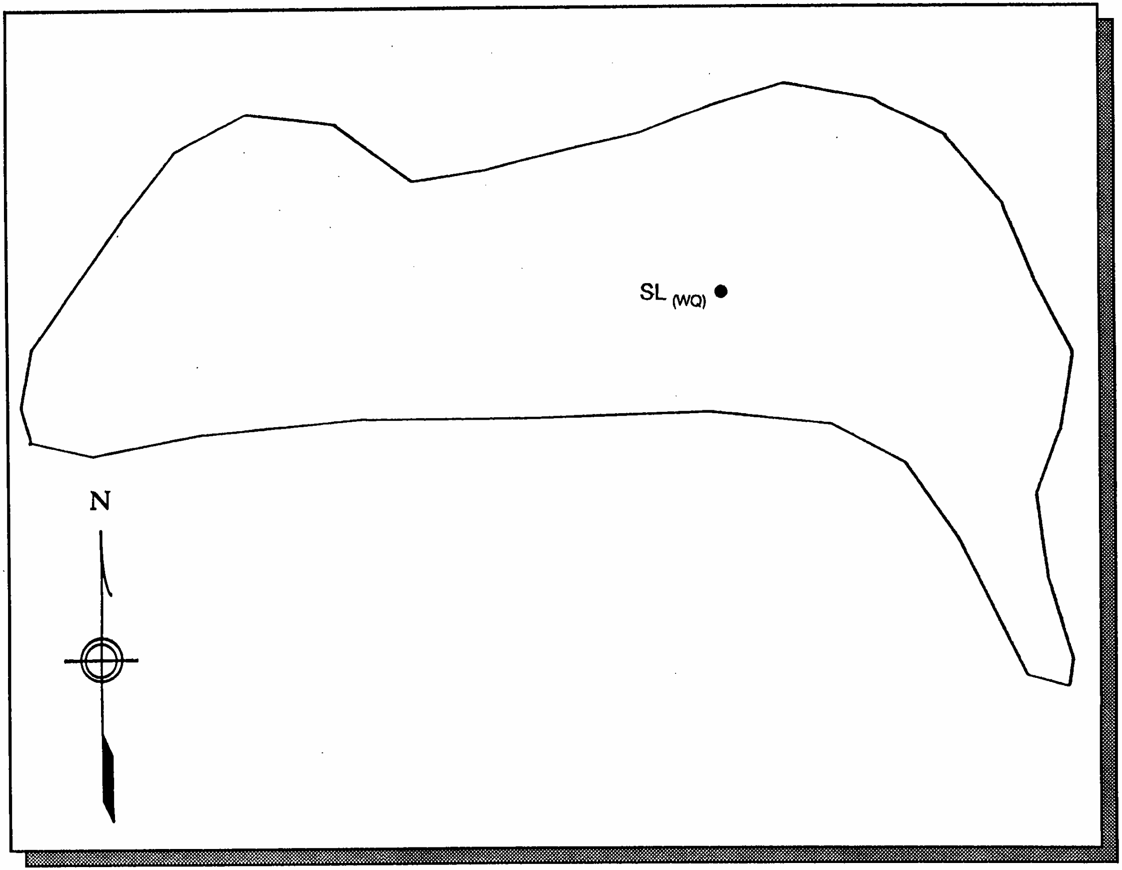

FIGURE 2-2. Location of in-lake sampling station on Schockopee Lake.

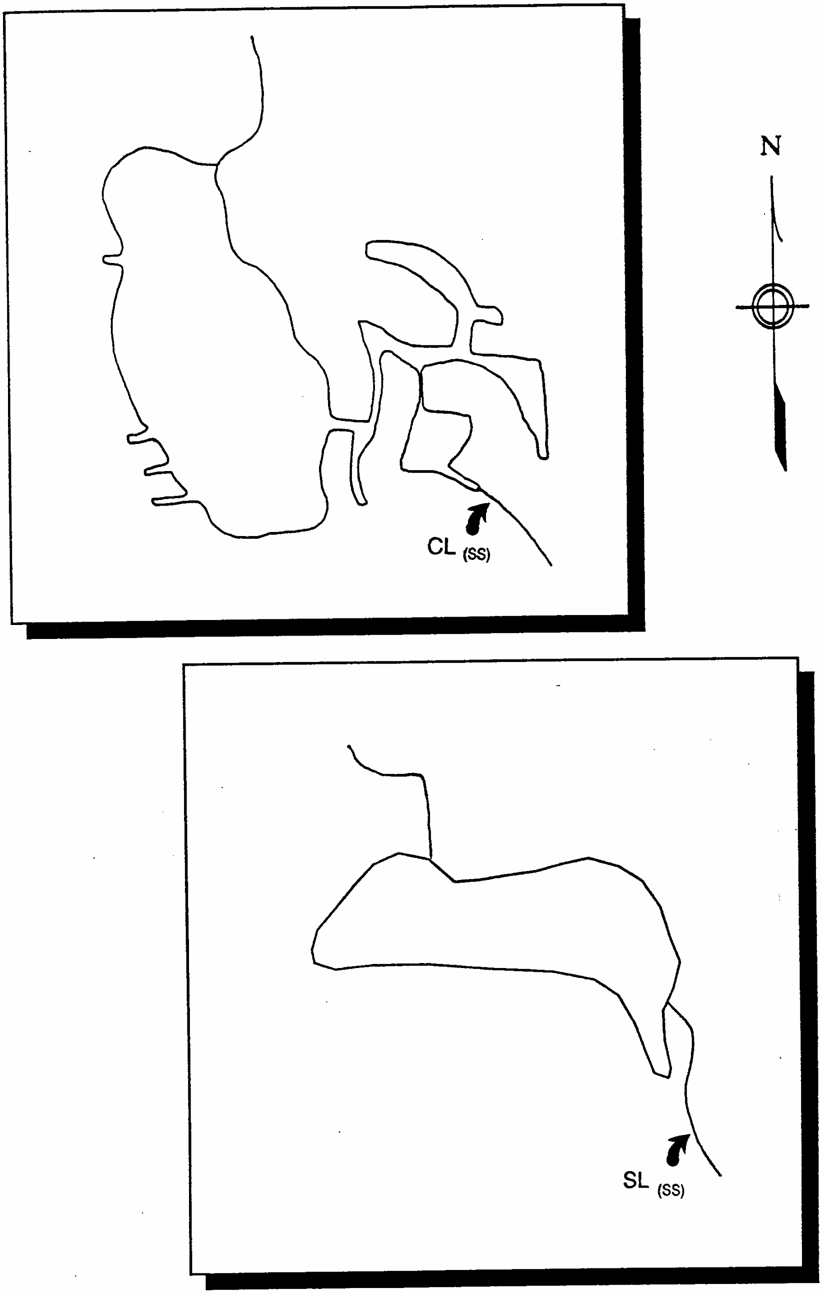

FIGURE 2-3. Locations of storm sampling on tributaries to Cree and Schockopee Lakes.

on ice in the dark and subsequently shipped to the IS&T analytical laboratory via overnight air freight. The samples were received and analyses were begun within 24 hours of collection. Parameters and methods used in the chemical determinations are listed in Table 2-1. Results were used to characterize mid-summer conditions in the lakes and to construct indices of trophic status.

TABLE 2-1. Chemical parameters and analytical methods used in evaluating water samples from Cree and Schockopee Lakes.

PARAMETER	METHOD	REFERENCE
Total phosphorus (TP)	Flow Injection Analysis	EPA, 1983
Soluble phosphorus (SP)	Flow Injection Analysis	EPA, 1983
Nitrate (NO3)	Flow Injection Analysis	EPA, 1983
Nitrite (NO2)	Flow Injection Analysis	EPA, 1983
Ammonia (N-NH4)	Flow Injection Analysis	EPA, 1983
Chlorophyll a (Chl-A)	Spectrophotometer	APHA, 1985
Total Suspended Solids (TSS)	Gravimetric	EPA, 1983
Fecal Coliform (FC)	Visual Count	APHA, 1985

NOTE: EPA = U.S. Environmental Protection Agency
APHA = American Public Health Association

Water samples were collected from tributaries of both lakes during a storm event on 14 September 1989 at stations $CL_{(SS)}$ and $SL_{(SS)}$ (Figure 2-3). One grab sample was taken from each tributary by Mr. Thomas Harlan (Cree Lake Association) in 1-liter sample bottles. The samples were immediately chilled and shipped to the IS&T analytical laboratory. These water samples were used to characterize tributary contributions of sediments and nutrients.

2.2.3 Biological Measurements

Vertical phytoplankton tow samples were collected at in-lake stations $CL_{(WQ)}$ and $SL_{(WQ)}$ using a half-meter 63 μ mesh plankton net. Tows were made from depths of 5 feet (1.5 m) in both lakes, from a depth of 16 feet (4.9 m) in Cree Lake, and from a depth of 10 feet (3.0 m) in Schockopee Lake. The latter depths were chosen so that the samples would include water from just below the thermocline. Samples were preserved in a 4% formalin solution, stored in 1-liter containers, and shipped with the water quality samples. To calculate total sample volume, the area covered by the mouth of the net was multiplied by the length of the tow (i.e., Π x 0.479 ft^2 x 5.0 ft). The total cell count was then divided by the sample volume to obtain the number of plankton cells per milliliter. Phytoplankton identifications were made using the Utermöhl method (Wetzel and Likens, 1958). The results were used to calculate a lake trophic index.

2.2.4 Sediment Core Analysis

Sediment samples were collected to determine the nature and extent of sedimentation in the Cree Lake canal system. Cores were collected at stations SED-1, SED-2, SED-3, and SED-4 (Figure 2-1) using a Wildco piston corer (Wildco Supply Company, Saginaw, MI). Each core was photographed and divided into visibly distinct layers. The depth and content of each layer was noted and described in the field. The uppermost layer of each core was analyzed in the laboratory for total phosphorus (TP), total Kjeldahl nitrogen (TKN), and volatile solids (VS). An Extraction Procedure (EP) toxicity test was performed on all core samples. Analytical methods are listed in Table 2-2.

TABLE 2-2. Analytical methods used to evaluate sediment samples from Cree and Schockopee Lakes.

PARAMETER	INSTRUMENT OR METHOD	REFERENCE
E.P. Toxicity Test	Extraction Procedure	EPA, 1986
Total Phosphorus	Flow Injection Analysis	EPA, 1983
Total Nitrogen	Flow Injection Analysis	EPA,1983
Volatile Solid Total	Gravimetric	USGS, 1979

NOTE: EPA = U.S. Environmental Protection Agency
USGS = U.S. Geological Survey

Measurements of unconsolidated sediment thickness were taken near the southeastern inlet of the canal system starting 98.5 feet (30 m) from the culvert and moving mid-channel approximately 250 feet (76.2 m) into the canal along the mid-line of the channel (Figure 2-4). At each station, a sediment probe was used to detect the depth to sediments and the probe rejection depth (i.e., maximum depth to which a probe will penetrate). Unconsolidated sediment thickness was calculated as the difference between rejection depth and depth to sediment.

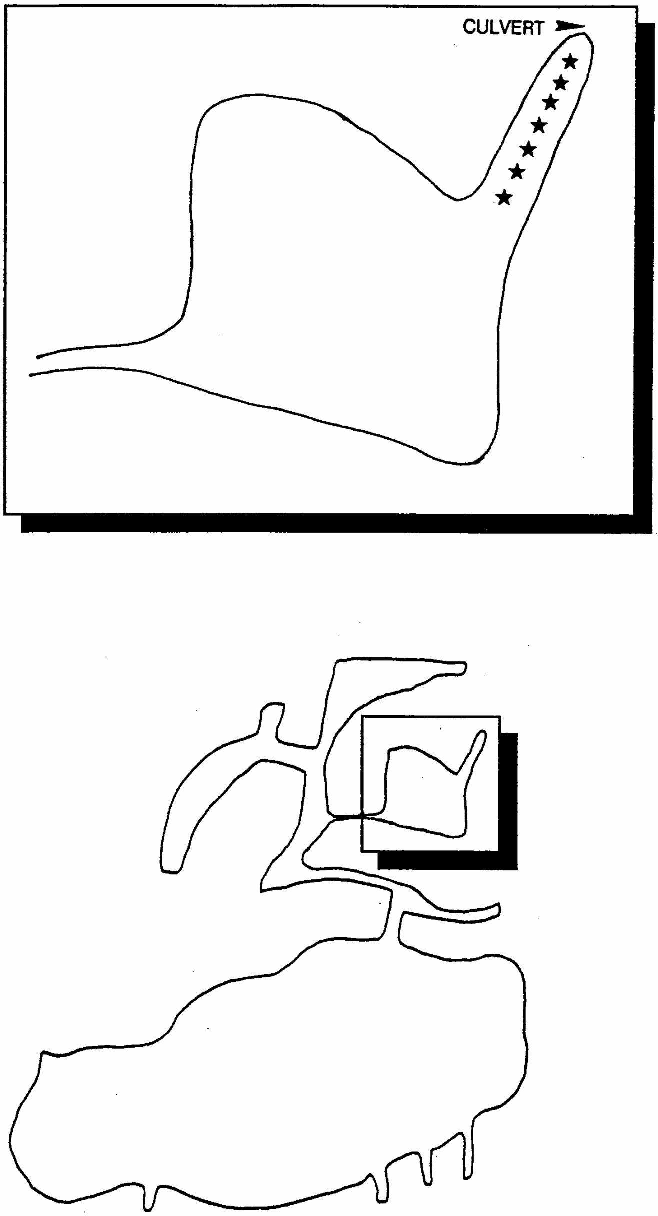

FIGURE 2-4. Locations of sediment depth stations in the Cree Lake canal system.

2.2.5 Aquatic Macrophyte Mapping

Hydrophytic vegetation occurring in both lakes was surveyed to quantify and map the distribution of floating, emergent, and submergent plant species. The perimeter of each lake was canvassed on foot and by boat. Plant specimens were photographed, identified, and collected in the field. Areal coverages were sketched and then digitized. Plant distribution maps were produced using the digitized data files.

2.2.6 Bathymetric Mapping

A bathymetric survey of Cree and Schockopee Lakes was conducted using an Eagle Mach 1 recording fathometer (Eagle Electronics, Catoosa, OK) operated from a 14-foot Jon boat. Geographical landmarks (e.g., houses) located along the lake shore were used to establish a survey grid of defined transects (Figures 2-5 and 2-6). Each transect was traversed at a constant boat speed and fathometer recordings were annotated at the beginning and end of each run. Fathometer traces were subsequently digitized. Bathymetric maps were produced using "Surfer" (Golden Software, Inc., Golden, CO), a contour mapping software package. Maximum depth, mean depth, and lake volume were calculated from area/volume ratio analysis of the bathymetric maps. Results of the Cree Lake bathymetric analysis were compared with previous bathymetric data to assess sedimentation rates.

2.3 WATERSHED SURVEY

A comprehensive effort was undertaken to describe conditions in the watershed. Special efforts were made to identify existing activities that could result in excessive sediment or nutrient loading (e.g., land clearing, construction, intensive tilling). Components of the watershed survey included:

- Climatic evaluation
- Hydrologic characterization
- Soil type delineation
- Land use delineation
- Sediment/nutrient modeling.

2.3.1 Climatic Evaluation

Two types of atmospheric information were obtained and analyzed during the study: (1) general climatic data (e.g., temperature, rainfall, solar radiation); and (2) precipitation chemistry data. General climatic conditions in the Cree Lake watershed were described from reports compiled by the U.S. Department of Commerce (DOC, 1968) and by the Soil Conservation Service (USDA, 1977). In addition, a weather simulation program (Nick and Lane, 1989) was used to construct 30-year monthly averages for maximum temperature, minimum temperature, total precipitation, storm duration, and solar radiation. Historical

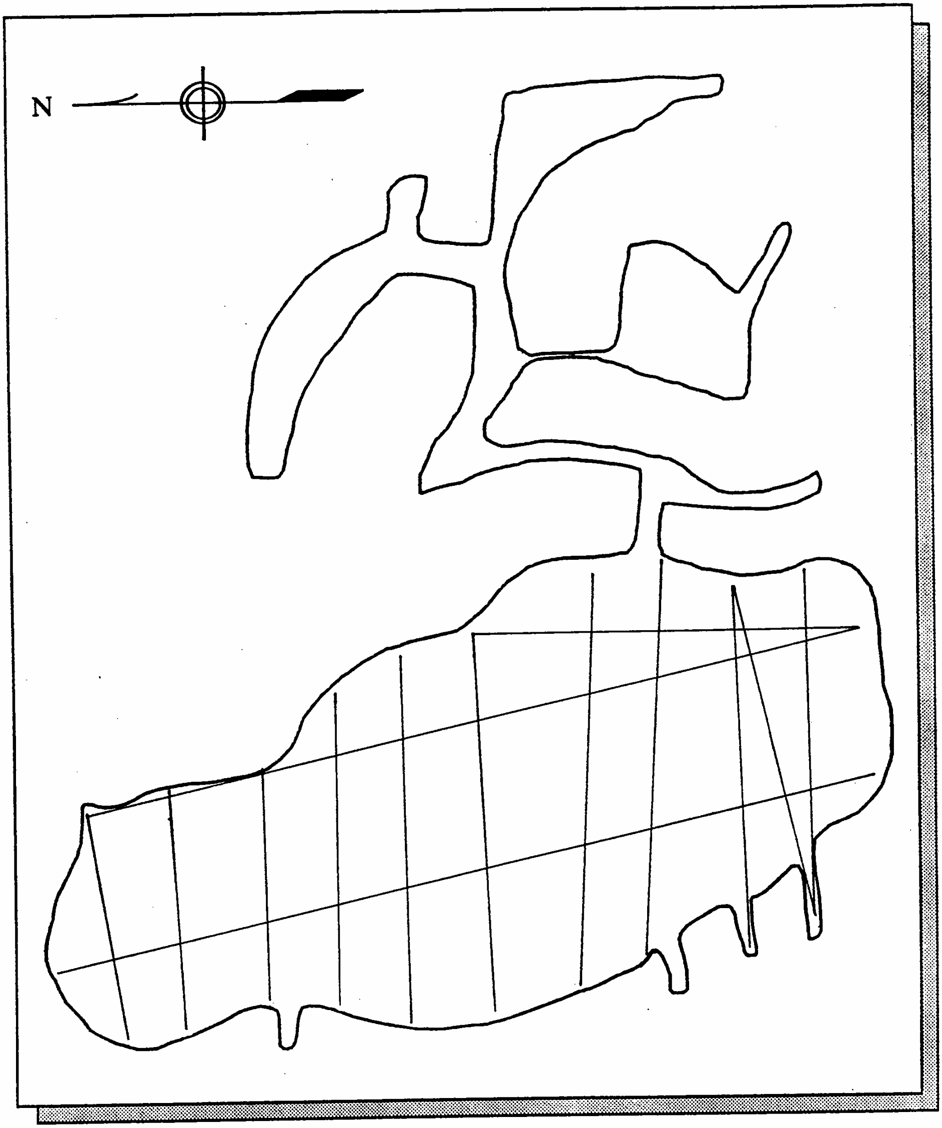

FIGURE 2-5. Survey grid used during bathymetric mapping of Cree Lake.

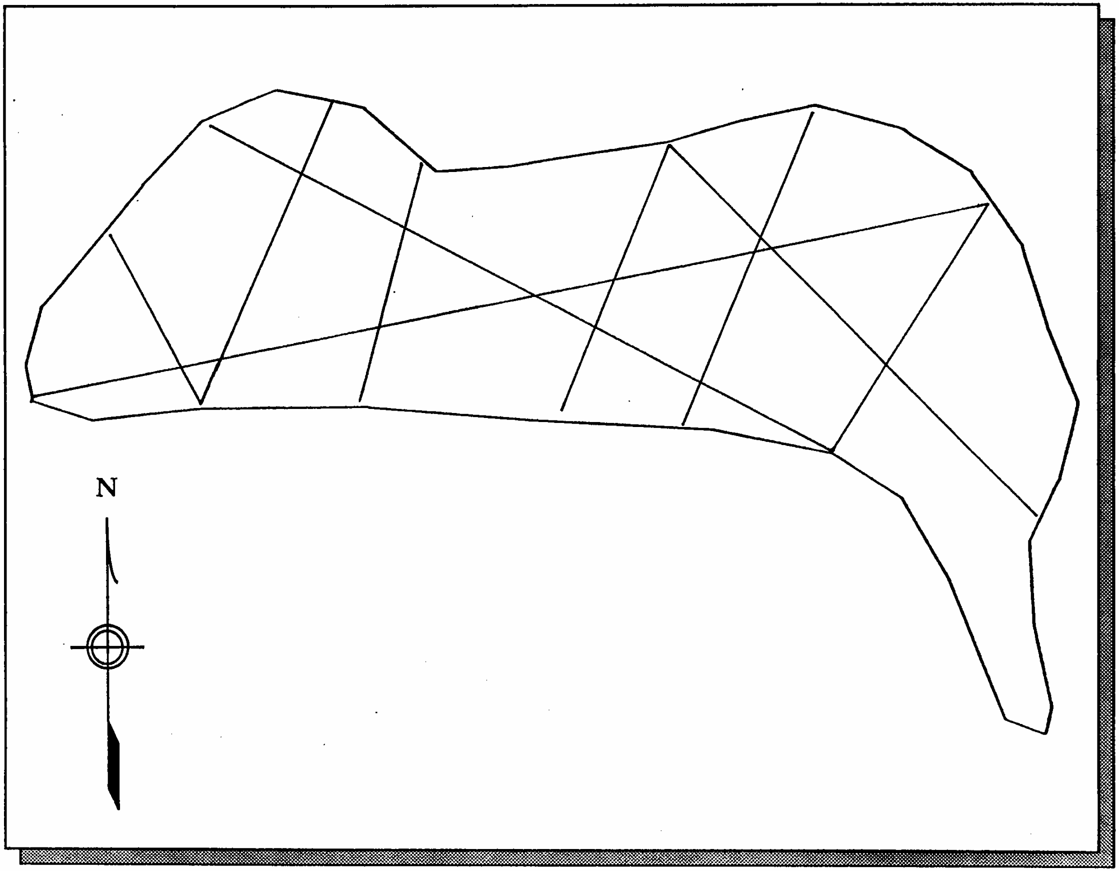

FIGURE 2-6. Survey grid used during bathymetric mapping of Schockopee Lake.

atmospheric information for the Fort Wayne area was obtained from the National Climatic Data Center and used to represent conditions in Noble County. Detailed descriptions of the parameters, statistics, and routines incorporated in the weather model are presented in the above-noted reference.

Because specific information on precipitation chemistry was unavailable for Cree and Schockopee Lakes, interpolated averages from data collected at the closest Great Lakes monitoring stations (i.e., Benton Harbor, Michigan and Put-in Bay, Ohio) were used to estimate total phosphorus and total nitrogen inputs from annual rainfall. No data were available to estimate dry loading.

2.3.2 Hydrologic Characterization

Hydrological characterization of the watershed centered around two types of analyses: (1) a general description of watershed and lake morphological attributes, including evaluation of physical several indices relating watershed size and shape to runoff behavior; and (2) calculation of an approximate mass-balance water budget. The watershed boundary was outlined on 7.5 Minute Series USGS topographic maps. A computerized opisometer (i.e., map distance/area measuring device) was used in conjunction with mechanical means to determine the nature of watershed features including total area and perimeter, axial length, average width, average slope, maximum and minimum slope, center of gravity, drainage pattern, drainage density, shape factor, compactness coefficient, eccentricity, and orientation. Lake surface area and perimeter were also measured. A description of the significance of each of these factors is presented below.

Area:	The extent of the ground surface inside the catchment, area is a fundamental unit of interest in all watershed studies.
Perimeter:	The length of the boundary around the catchment, perimeter is helpful in determining watershed shape characteristics.
Axial Length:	The distance between the watershed outlet (i.e., lake overflow) and the farthest point on the catchment boundary, axial length is helpful in determining the time required for rain water falling on the most remote section of the catchment to reach the overflow (i.e., maximum time necessary for trans-watershed flow).
Average Width:	Literally, the ratio of catchment area to axial length, average width is a shape descriptor.
Average slope:	A measure of elevation change per unit of horizontal distance within the catchment, average slope describes the general "steepness" of the watershed. "Steepness" partly determines the velocity (i.e., erosional capacity) of runoff.

Minimum slope:	Another measure of elevation change per unit of horizontal distance within the catchment, minimum slope describes the lowest degree of "steepness" in the watershed. This parameter is often used with its counterpart, maximum slope, to indicate the range of "steepness."
Maximum slope:	A third measure of elevation change per unit of horizontal distance within the catchment, maximum slope describes the highest degree of "steepness" in the watershed. This parameter is often used with its counterpart, minimum slope, to indicate the range of "steepness."
Center of Gravity:	The areal centroid of the catchment, this measure pinpoints the exact center of the watershed.
Drainage Pattern:	The arrangement of natural channels within a catchment, drainage pattern not only describes the layout of the streams but also indicates the types of existing soils/bedrock (i.e., drainage configurations are dependent on the erosional resistance of the existing substrate).
Drainage Density:	The ratio of catchment stream length to catchment area, drainage density measures the efficiency of drainage afforded by defined channels (i.e., extensive stream networks lead to efficient drainage).
Form Factor:	The ratio of watershed average width to axial length, the form factor indicates the relative shape of the watershed.
Compactness Coefficient:	The ratio of the perimeter of the watershed to the perimeter of a circle with an equal area, the compactness coefficient indicates the nature and timing of runoff contributions to stream flow (i.e., circular watersheds are regular in shape and tend to have all areas contributing runoff equally within a distinct time span; non-circular watersheds tend to have nonuniform and less predictable runoff characteristics).
Eccentricity:	A measure relating watershed shape to an ellipse, this parameter also indicates the nature and timing of runoff contribution to stream flows.
Orientation:	Synonymous with "aspect", orientation indicates the compass direction toward which most slopes in the watershed face.

An annual water budget was developed for Cree and Schockopee Lakes based on estimates of water mass inputs and outputs (Table 2-3). Parameters considered as inputs included direct rainfall, runoff, and groundwater inflow. Parameters considered as outputs included lake outlet overflow, evaporation, and basin leakage. Annual rainfall volumes applied to the water budget were derived from 30-year averages produced by the computerized weather generator (Section 2.3.1). Runoff volumes were calculated using the

Curve Number Method described in U.S. Soil Conservation Service Technical Release 55 (USDA, 1986). Lake evaporation was interpolated from pan evaporation figures supplied in the Weather Atlas of the United States (DOC, 1968). Because data for springs and leakage in the lake were unavailable, these factors were assumed to be negligible. Lake overflow was calculated as the residual of inflow minus evaporation. No other water inflows or outflows were identified.

TABLE 2-3. Mass-balance relationship and input/output parameters considered in the water budget.

MASS-BALANCE RELATIONSHIP:	Inputs = Outputs
INPUTS:	OUTPUTS:
Rainfall (monthly/annual)	Lake Overflow (monthly/annual)
Stream flow/Runoff (monthly/annual)	Evaporation (monthly/annual)
Under-basin Springs[1]	Under-basin Leakage[1]

[1]Assumed to be 0 because no data were available for these parameters.

In addition to water budget parameters, estimates were made for potential evapotranspiration and hydraulic retention time. Potential evapotranspiration (PET) is a measure of maximum possible evaporation through the soil and vascular plants, given an unlimited water supply. Estimates of PET were generated using the Thornthwaite Method (Thornthwaite and Mather, 1956), an empirical technique based on mean monthly temperatures. This technique was chosen over other methods because the information requirements were readily met by the existing climatic data.

Hydraulic retention time is a measure of the time required for the volume of lake inflow water to equal the volume of the lake itself. It can be thought of as the period of time necessary to completely replace the volume of the lake. For this study, hydraulic retention time was computed as the ratio of lake water volume to the annual inflow water volume. Results were expressed in terms of years.

2.3.3 Soil Type Delineation

Erodible and non-erodible soils in the Cree Lake watershed were identified using SCS soil manuals and erosion study documents for Noble County (NCSWCD, 1987; USDA, 1977). Areal coverages of these soils were extracted from existing maps and then digitized. Erodible soil maps were produced for this report using IS&T proprietary software. Results were used as input parameters for modeling sediment/nutrient dynamics (Section 2.3.5).

2.3.4 Land Use Delineation

Land use coverages in the Cree Lake watershed were identified and delineated using a combination of (1) USGS 7.5 minute series topographic maps; (2) aerial photographs (scale = 1 to 2000); and (3) site reconnaissance. The watershed boundary was outlined on topographic maps and digitized along with key geographical features (e.g., lake shorelines, streams, roads, towns). Using aerial photographs, land uses were delineated and assigned to one of sixteen possible categories (Table 2-4). The land uses were then digitized and overlain onto the watershed boundary and geographical feature files. Coverage maps and tabular summaries of land use in the whole watershed and in sub-basins were produced for this report with IS&T proprietary software. Results were used as input parameters for modeling sediment/nutrient dynamics (Section 2.3.5). All maps were verified during ground reconnaissance visits.

TABLE 2-4. Land use categories designated in the watershed surveys.

1)	Water Surface
2)	Wetlands (including approx. stream corridors)
3)	Forest (tree groups larger than 1/4 acre)
4)	Open Land/Vacant Lots (no structures or livestock)
5)	Pasture (grazed lands)
6)	Row Crops (corn, beans, etc.)
7)	Non-row Crops (grains)
8)	Orchard
9)	Feedlot
10)	Low Density Residential (1 dwellings/acre)
11)	Medium Density Residential (2-4 dwellings/acre)
12)	High Density Residential (5 or more dwellings/acre)
13)	Commercial/Industrial (industrial parks, malls)
14)	Institutional (schools, parks, golf courses)
15)	Bare Ground (construction sites)

2.3.5 Sediment/Nutrient Modeling

Information on land use, climate, soils, and hydrology were combined to provide input parameters for use in the Agricultural Nonpoint Source Pollution Model (AGNPS), a system developed by the Agricultural Research Service (ARS) in cooperation with the Minnesota Pollution Control Agency and the Soil Conservation Service. The model was designed to evaluate sediment, nutrient, and hydrologic quality of runoff from land in agricultural regions. AGNPS operates on a grid basis and requires the watershed to be divided into a series of uniform square areas called "cells." Twenty two physical and chemical characteristics must be defined and entered into a data base for each cell before the model is run (Table 2-5). Potential pollutants are routed through the watershed beginning at cells along the basin divide and are moved toward the outlet in a stepwise manner. Depending on the defined parameters, each cell exerts an influence on the runoff, either increasing or diminishing the nonpoint pollutant load. Sediment, nutrient, and hydrologic characteristics may be summarized for any cell along the flow path and at the watershed outlet. The model provides estimates for single precipitation events only, and, therefore, requires the user to define a "design storm" for the analysis.

TABLE 2-5. Input parameters used in the AGNPS model[1].

TITLE	DESCRIPTION
Cell Number	ID number of current cell
Receiving Cell	ID number of cell receiving outflow from current cell
SCS Curve Number	Relates runoff mass to rainfall mass (inches)
Field Slope	Mean slope of fields (%)
Slope Shape	Shape of slopes (i.e., concave, convex, or uniform)
Slope Length	Mean slope length of fields (feet)
Channel Slope	Mean slope of stream channel (%)
Side Slope	Mean slope of stream channel banks (%)
Roughness	Manning's "roughness" coefficient for channels
Soil Erodibility	K-Factor from Universal Soil Loss Equation
Crop Practice	C-Factor from Universal Soil Loss Equation
Conservation Practice	P-Factor from Universal Soil Loss Equation
Surface Condition	Indicates degree of land surface disruption
Aspect	Principal drainage direction
Soil Texture	Gross texture of the soil (i.e., sand, silt, clay, or peat)
Fertilization	Level of added fertilizer
Incorporation	Percentage of fertilizer left on soil after the storm
Point Source Flag	Indicates presence/magnitude of point source (e.g., treatment plant)
Gully Source	Estimate of the magnitude of gully erosion
COD	Level of chemical oxygen demand generated
Impoundment Flag	Indicates presence/number of terrace systems
Channel Flag	Indicates presence/number of defined streams

[1] Parameters represent estimated conditions within each cell.

Based on the recommendations of AGNPS developers, the Cree Lake watershed was divided into a series of 45-acre cells. Values for the parameters listed in Table 2-5 were assigned to each cell. The design storm chosen for this exercise was the 2-year, 24-hour event (i.e., the largest storm lasting 24 hours that can be expected to occur once every 2 years). This storm was chosen because: (1) suitable climatic input data were easily acquired; (2) the storm was large enough to produce meaningful model output; and (3) the storm was small enough to be considered fairly common. Nutrient, sediment, and runoff maps highlighting potential watershed "trouble spots" were produced using the AGNPS Graphical Interface System.

2.3.6 Septic System Inputs

All available septic system data were obtained from the Noble County Health Department, the U.S. Census Bureau, and other appropriate county, state, and Federal agencies. This information included figures for age, loading level, and loading capacity of systems potentially impacting the lakes. Data on population (i.e., total population and individuals per dwelling), soil conditions (i.e., slope, drainage characteristics), and expected system life spans (i.e., half-life figures for systems in various Indiana soils) were collected. Overall load estimates, age values, and life span data were combined for systems near the lakes to provide an assessment of overall septic load to each water body.

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SECTION 3. SURVEY RESULTS AND DISCUSSION

Results of the literature, lake, and watershed surveys are presented in this section of the report. Most of the discussion centers on the findings of the lake and watershed surveys, with references to the literature search assuming a supporting role. Identification of sediment and nutrient sources within the watershed is provided following presentation of survey results and serves to summarize the study findings in management-oriented terms.

3.1 LAKE SURVEY RESULTS

The findings of the Cree and Schockopee lake surveys are presented in the following paragraphs. Components of the investigation included in-situ, chemical, and biological water quality measurements; lake sediment core analyses; aquatic macrophyte mapping; and bathymetric mapping. Summertime conditions in the lakes were characterized based on the survey data and a Bonhomme eutrophication index was calculated.

Visual observation of the Cree Lake canal system indicated that the canals were heavily infested with aquatic plants. Thick mats of filamentous algae were present along the shorelines and a layer of duckweed species covered the entire surface. Boating was restricted throughout the canals because of submersed vegetation and shallow depth. The substrate was rich black organic muck, characteristic of systems receiving substantial amounts of plant detritus. In contrast, the main body of Cree Lake had a healthy population of aquatic plants and there was no apparent loss of depth. The substrate was sandy and the waters were navigable.

Visual observation of the Schockopee system revealed ample macrophyte coverage along the lake shores, especially near the southeastern tributary. Large algal populations were in evidence but did not appear to be at nuisance levels. The original sandy-marl sediments of Schockopee Lake were obscured by a layer of mucky, organic material.

3.1.1 In-situ Water Quality

In-situ water quality measurements collected at Cree Lake are listed in Table 3-1 and presented graphically in Figures 3-1a through 3-1d. These data indicate that Cree Lake was thermally stratified when the samples were collected. The lake thermocline was located between 8 and 18 feet (2.4 and 5.5 m), as indicated by the maximum rate of decrease in the temperature at those depths (Figure 3-1a). The shape of the DO profile measured at Cree Lake (Figure 3-1b) is best described as clinograde, with well-oxygenated waters near the surface (i.e., epilimnion), tapering dramatically toward anoxia in the 5 to 10 foot (1.7 to 3.0 m) depth range. This condition is usually observed during periods of thermal stratification (generally in summer and winter) when oxygen consumption exceeds oxygen production in the bottom waters (i.e., hypolimnion). Because water circulation is reduced during

TABLE 3-1. Results of in-situ water quality sampling conducted at Cree Lake on 13 July 1989.

Depth (feet)	Depth (m)	Temperature (°F)	Temperature (°C)	pH	DO (mg/l)	Conductivity (mmho/cm^2)
0.0	0.0	79.5	26.4	8.14	6.95	0.463
4.0	1.2	79.7	26.5	8.12	6.82	0.463
6.0	1.8	79.7	26.5	8.12	6.70	0.463
8.0	2.4	79.5	26.4	8.02	5.12	0.463
10.0	3.1	73.4	23.0	7.78	5.04	0.479
12.0	3.7	67.8	19.9	7.99	6.87	0.499
14.0	4.3	62.1	16.7	7.90	6.16	0.507
16.0	4.9	57.7	14.3	7.67	0.39	0.515
18.0	5.5	54.5	12.5	7.65	0.12	0.512
20.0	6.1	51.8	11.0	7.61	0.08	0.515
22.0	6.7	50.5	10.3	7.57	0.12	0.522
24.0	7.3	48.9	9.4	7.45	0.08	0.534
26.0	7.9	48.2	9.0	7.41	0.06	0.540
27.0	8.2	48.0	8.9	7.40	0.09	0.542

Secchi Disk Transparency: 9.3 feet (2.8 m)

Light Transmission at 3 feet (0.91 m): 67.5 %

stratification, less oxygen can be redistributed to the hypolimnion from the surface. A slight increase in DO concentration was observed in Cree Lake at the 12 to 16 foot (3.7 to 4.9 m) depth range and can be termed an "oxygen maximum." The phenomenon is common in stratified waters and is the result of oxygen produced by algal populations that develop more rapidly than they sink. The occurrence of oxygen maxima most often coincides with peak growth of rooted and submersed aquatic macrophytes where oxygen enriched waters dissipate into the metalimnion layer (Wetzel, 1983).

Measurements of pH ranged between 8.2 (surface) and 7.4 (bottom) and are displayed in Figure 3-1c. The majority of open lakes have a pH range between 6 and 9. Such lakes are regulated by a natural carbonate buffering system. The distribution of pH is influenced by photosynthetic utilization of carbon dioxide (CO_2) in the trophogenic zone and respiratory generation of CO_2 throughout the water column and sediments. If the accumulation of CO_2 exceeds oxygen consumption and the hypolimnion becomes anaerobic, the pH will decrease markedly. Where photosynthetic activity is particularly intense, as was the case in the metalimnion, the pH will increase in response to the decrease in CO_2 (Figure 3-1c).

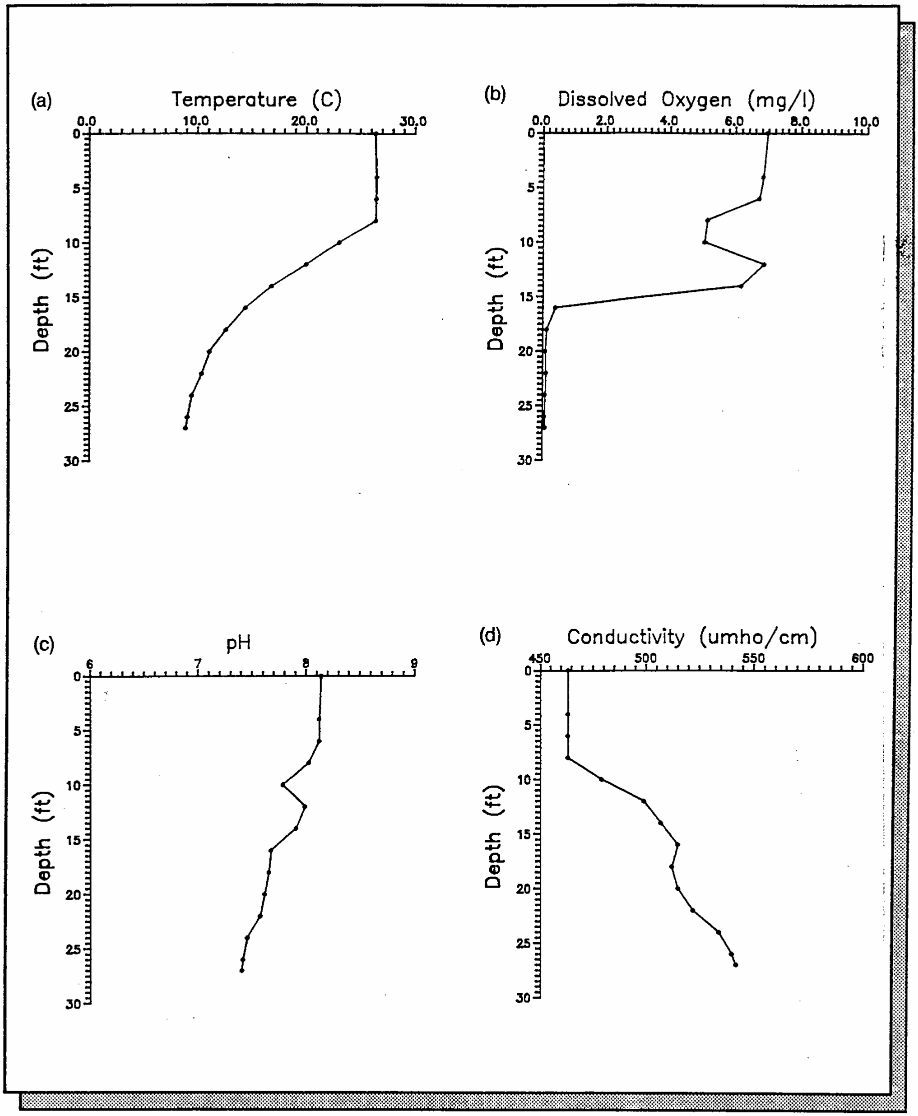

FIGURE 3-1. Graphical representations of in-situ water quality data taken at Cree Lake on 13 July 1989.

An inverse clinograde curve was observed for the conductivity measurements. It is common in anoxic waters for the specific conductance to increase in the hypolimnion. The total dissolved solids, including silt and clay particles, organic matter, and micro organisms are typically present in greater concentrations in the hypolimnion.

Water clarity was average, with a Secchi disk depth of 9.25 feet (2.8 m). This depth is within the 50th percentile of 400 previously studied Indiana lakes (IDEM, 1986). Light transmission was 67.5% at a depth of 3 feet (0.9 m).

In-situ water quality measurements for Schockopee Lake are listed in Table 3-2 and presented graphically in Figures 3-2a through 3-2d Schockopee Lake was also thermally stratified (Figure 3-2a) with the lake thermocline located between 6 and 16 feet (1.8 and 4.9 m). The DO concentration was greatly reduced beneath the thermocline (Figure 3-2b). Again, this condition is typical of eutrophic lakes with an anaerobic hypolimnion. Measurements of pH were within the range of a typical open lake (Figure 3-2c). The specific conductance increased from the surface waters to the hypolimnion (i.e., 48 to 61 μmho/cm). Secchi disk depth was 3 feet (0.9 m), This depth is within the 36th percentile

TABLE 3-2. Results of in-situ water quality sampling conducted at Schockopee Lake on 13 July 1989.

Depth (feet)	Depth (m)	Temperature (°F)	Temperature (°C)	pH	DO (mg/l)	Conductivity (mmho/cm^2)
0.0	0.0	78.4	25.8	8.54	12.00	0.485
2.0	0.6	76.8	24.9	8.39	10.73	0.486
4.0	1.2	76.6	24.8	8.32	10.12	0.488
6.0	1.8	74.7	23.7	7.69	5.86	0.501
8.0	2.4	70.8	21.6	7.41	0.29	0.531
10.0	3.1	62.1	16.7	7.46	0.17	0.556
12.0	3.7	58.3	14.6	7.55	0.13	0.556
14.0	4.3	54.5	12.5	7.54	0.11	0.563
16.0	4.9	52.7	11.5	7.50	0.07	0.569
18.0	5.5	49.6	9.8	7.44	0.12	0.579
20.0	6.1	48.4	9.1	7.40	0.09	0.584
22.0	6.7	47.3	8.5	7.35	0.09	0.593
24.0	7.3	46.8	8.2	7.33	0.09	0.604
25.0	7.6	46.6	8.1	7.32	0.09	0.609

Secchi Disk Transparency: 3.1 feet (.9 m)

Light Transmission at 3 feet (0.91 m): 37.6 %

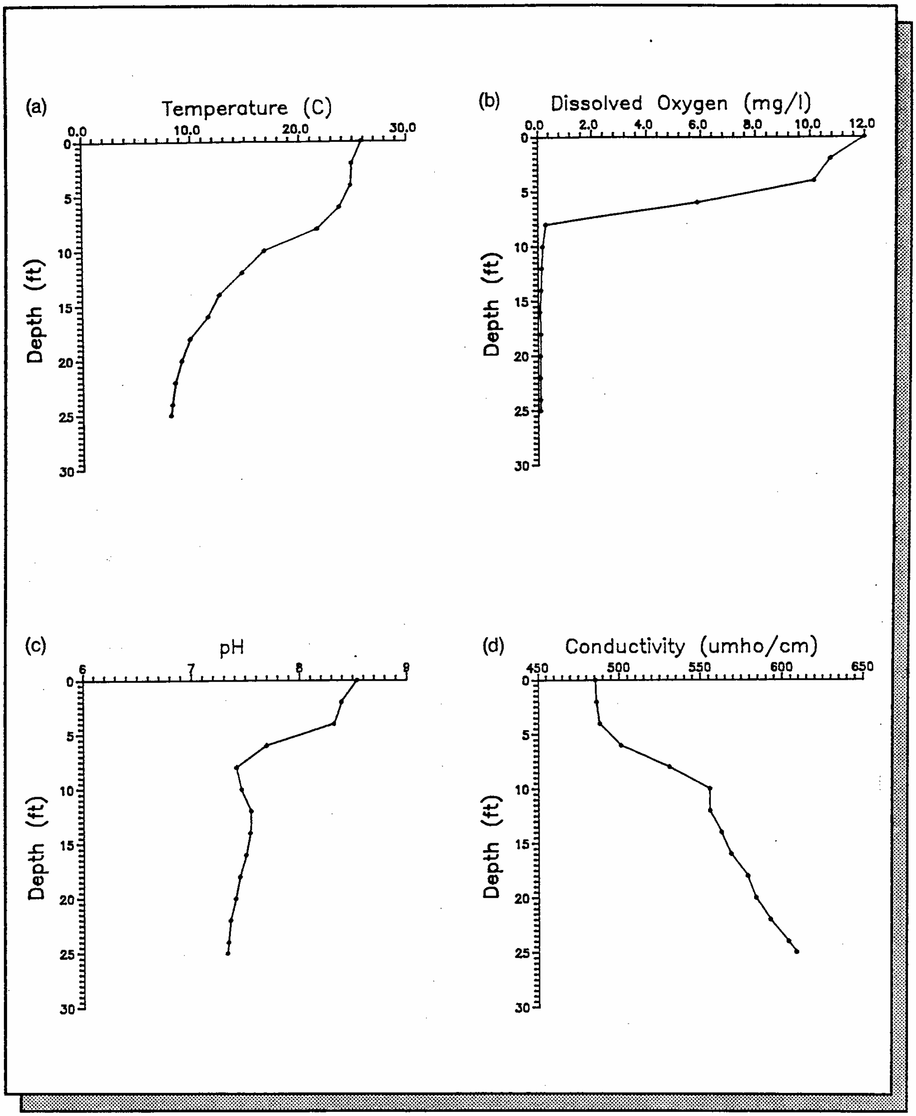

FIGURE 3-2. Graphical representations of in-situ water quality data taken at Schockopee Lake on 13 July 1989.

of 400 previously studied Indiana lakes (IDEM, 1986). Light transmission was 37.6% at a depth of 3 feet (0.9 m).

3.1.2 Chemical Water Quality

Chemical water quality measurements for the Cree Lake samples are listed in Table 3-3. The values obtained for Chlorophyll a (Chl a) are within the range of those found in both mesotrophic and eutrophic lakes (Wetzel, 1983). In all three samples, the fecal coliform cell concentrations were below the acceptable maximum for public swimming waters (i.e., 200-220 organisms per 100 ml). The high concentration of ammonia at 26 feet (7.9 m) was attributed to anaerobic conditions at that depth since ammonia concentrations are typically elevated in poorly oxygenated waters. The nitrite-nitrate (NO_2+NO_3) concentrations decreased in the hypolimnion as a result of denitrification processes that occur in anaerobic environments. The absence of detectable nitrite (NO_2) in the lake was expected. Nitrite is readily converted by the bacteria *Nitrobacter* to nitrate (NO_3) and rarely accumulates unless organic pollution is high. Relatively high concentrations of total Kjeldahl nitrogen (TKN) were observed near the sediment-water interface. TKN represents organically-bound nitrogen and elevated concentrations are representative of the high levels of organic matter present in the hypolimnion. Total phosphorus (TP) concentrations in Cree Lake were typical of mesotrophic or slightly eutrophic waters. Increased total and soluble phosphorus content near the bottom is common in eutrophic lakes with strongly clinograde oxygen profiles (Wetzel, 1983). Much of the increase was probably due to soluble phosphorus (SP) near the sediment-water interface, as 83% of the TP near the lake bottom was from SP (Table 3-3). The ratio of total nitrogen (TN) to TP (N:P) at depths above the thermocline was above 75:1. N:P ratios above 20:1 are characteristic of lakes where phosphorus is the limiting nutrient. Typically, land and atmosphere based sources provide more nitrogen than can be fully utilized by photosynthesis with a finite supply of phosphorus.

TABLE 3-3. Results of water chemistry sampling conducted at Cree Lake on 13 July 1989.

Depth (feet)/(m)	Chl a (mg/m_3)	Fecal (#/100ml)	$N\text{-}NH_4$ (mg/l)	NO_2 (mg/l)	NO_2+NO_3 (mg/l)	SP (mg/l)	TKN (mg/l)	TP (mg/l)
0.0/0.0	4.7	35.0	0.330	0.000	0.488	0.015	0.704	0.015
13.0/3.9	7.1	3.0	0.240	0.000	0.674	0.013	0.680	0.016
26.0/7.9	9.9	10.0	2.110	0.000	0.059	0.371	3.407	0.448
Averages	7.2	16.0	0.893	0.000	0.407	0.133	1.597	0.160

Similar analyses were performed for water quality in Schockopee Lake. Results of in-lake samples collected at station $SL_{(WQ)}$ are listed in Table 3-4. The chlorophyll a concentrations at all depths of the lake were in the range of those values found in eutrophic lakes (Wetzel, 1983). The fecal coliform cell concentrations were much higher than those in Cree Lake, but were well below the maximum acceptable limit for swimming waters. The increased ammonia (NH_4) concentrations and the decreased nitrite and nitrate (NO_2+NO_3) concentrations in the hypolimnion were typical of anaerobic environments. The concentration of (NO_2+NO_3) in the epilimnion was within the range (i.e., 0.5 to 1.5 mg/l) of those found in eutrophic lakes in regions bordering the southern Great Lakes (Wetzel, 1983). Only trace amounts of nitrite were detected. The average TKN concentration was the same as the concentration found in Cree Lake. Total phosphorus levels in Schockopee Lake were typical of mesotrophic or eutrophic waters. Both soluble phosphorus (SP) and total phosphorus (TP) concentrations increased near the sediment-water interface. SP made up less than 32% of TP for all the samples taken. This observation suggests that most of the TP in the water column contained a high fraction of dissolved colloidal organic phosphorus that is slowly released and cycled (Wetzel, 1983). The N:P ratios were between 33:1 and 53:1, indicating that Schockopee is phosphorus limited.

TABLE 3-4. Results of water chemistry sampling conducted at Schockopee Lake on 13 July 1989.

Depth (feet)/(m)	Chl a (mg/m$_3$)	Fecal (#/100ml)	N-NH_4 (mg/l)	NO_2 (mg/l)	NO_2+NO_3 (mg/l)	SP (mg/l)	TKN (mg/l)	TP (mg/l)
0.0/0.0	40.9	24.0	0.090	0.005	0.918	0.016	0.818	0.052
12.0/3.7	6.7	80.0	0.730	0.069	0.764	0.011	1.392	0.040
24.0/7.3	7.7	50.0	1.600	0.000	0.075	0.211	2.474	0.694
Averages	18.5	51.3	0.807	0.025	0.586	0.079	1.561	0.262

Results of storm event sampling are presented in Table 3-5. With the exception of ammonia (N-NH_4), the highest nutrient and solids concentrations were observed in the tributary east of Schockopee Lake, at site $SL_{(SS)}$. This finding reflects the predominance of row-crop agriculture in the large sub-basin draining into the lake via this tributary. Elevated solids loading is especially characteristic of erosion-prone areas such as those associated with row-crop practices. By reviewing the relative contributions of total phosphorus and soluble phosphorus (TP and SP, respectively), it can be seen that the overwhelming majority of phosphorus entering Schockopee Lake from stream $SL_{(SS)}$ was sediment bound (i.e., SP was

TABLE 3-5. **Results of storm event sampling in tributaries to Cree and Schockopee Lakes.**

STATION	$N\text{-}NH_4$ (mg/l)	TKN (mg/l)	NO_3 (mg/l)	SP (mg/l)	TP (mg/l)	TSS (mg/l)
$CL_{(SS)}$	0.047	1.035	0.405	0.024	0.065	7.40
$SL_{(SS)}$	0.006	1.053	1.378	0.049	0.111	40.20

nearly negligible). Reducing sediment inputs from upland sites in the watershed, therefore, would be expected to result in reduced phosphorus loading, as well.

The moderately high concentration of TSS found in the tributary east of Cree Lake at site $CL_{(SS)}$ is possibly a result of overflow from Schockopee Lake. During a storm event, most of suspended sediment entering into Schockopee Lake is unable to settle due to the short retention time (Section 3.2.2). As in the Schockopee tributary, the majority of phosphorus was particulate bound. Again, reducing the amount of sediment reaching the tributary would be expected to reduce phosphorus input. The moderately high levels of TKN found in this stream, as in the Schockopee tributary, were probably the result of organic sediment flushing during the storm event.

3.1.3 Phytoplankton

Results of phytoplankton identification and enumeration revealed a fairly diverse algal community in both Cree and Schockopee Lakes. The phytoplankton communities were numerically dominated by blue-greens. In Cree Lake, a total of 22 species in 4 classes was observed (Table 3-6). At a depth of 5 feet (1.5 m), *Microcystis aeruginosa* was prevalent while at 16 feet (4.9 m), *Aphanizomenon flos-aquae* dominated. In Schockopee Lake, a total of 28 species in 4 classes was represented (Table 3-7). *Aphanizomenon* dominated at 5 feet (1.5 m) and 10 feet (3.0 m) depths. *Anabaena* was also numerically abundant. *Microcystis, Aphanizomenon* and *Anabaena* are associated with advanced eutrophic conditions. All three species are known to produce lethal toxins under certain conditions and can be associated with summer fish kills (Cole, 1979).

3.1.4 Sediments

Sediment core descriptions for Cree Lake are presented in Table 3-8. Analytical results for TP, TKN, and volatile solids (VS) are listed in Table 3-9. The sediment descriptions indicated that organic matter comprised the major portion of the sediment cores at all four stations in the waterbody. The dense communities of aquatic vegetation in these areas contributed to the accumulation of organic matter through the sloughing of leaves and stems. The presence of plant detritus is consistent with the relatively high values of TKN and volatile solids observed at all stations. As aquatic vascular vegetation decomposes, large quantities of organic nitrogen are released by the plant material and are absorbed by the

TABLE 3-6. Results of Cree Lake phytoplankton identification and enumeration samples collected on 16 July 1989.

	SURFACE	THERMOCLINE
DEPTH OF SAMPLE (feet) (m)	5.00 1.52	16.00 4.87
SAMPLED WATER VOLUME (feet^3) (m^3)	3.60 0.10	11.53 0.33
SPECIES:	NUMBER OF CELLS (count in millions):	
Chlorophyta (green algae)		
Chlamydomonas (snowii)	0.022	
Eudorina elegans	Scan	
Pandorina morum	Scan	Scan
Selenastrum westii	0.340	
Staurastrum paradoxum	Scan	
Tetraspora lacustris	Scan	
unidentified unicell	0.022	
Chrysophyta (diatoms, chrysophytes)		
Fragilaria crotonensis	Scan	Scan
Dinobryon divergens	Scan	Scan
Melosira islandica		Scan
unidentified centric (7μ)	0.004	
Pyrrhophyta (dinoflagellates, cryptomonads)		
Ceratium hirundinella	1.595	0.514
Cyanophyta (blue-green algae)		
Anabaena planktonica	3.253	5.141
Aphanizomenon flos-aquae	9.269	40.485
Aphanocapsa pulchra	0.341	
Aphanotheca gelatinosa	Scan	
Aphanotheca microscopica	Scan	Scan
Coelosphaerium naegelianum	2.126	4.284
Microcystis aeruginosa	15.669	0.343
Oscillatoria planctonica	0.595	1.971
Oscillatoria tenuis	2.786	6.940
Unknown		
microflagellate (4x9 μ)	0.276	0.386
Total Cells Per Sample (count in millions)	36.298	60.064

NOTE: "Scan" indicates species was observed during preliminary, non-quantitative scan.
Many large clumps of dead Microcystis aeruginosa were observed but not counted.

TABLE 3-7. **Results of Schockopee Lake phytoplankton identification and enumeration samples collected on 17 July 1989.**

	SURFACE	THERMOCLINE
DEPTH OF SAMPLE (feet) (m)	5.00 1.52	10.00 3.05
SAMPLED WATER VOLUME (feet^3) (m^3)	3.60 0.10	7.21 0.20
SPECIES:	NUMBER OF CELLS (count in millions):	
Chlorophyta (green algae)		
Ankistrodesmus falcatus	Scan	
Chlamydomonas globosa	Scan	0.347
Coelastrum microporum	Scan	
Oocystis borgei	Scan	0.174
Oocystis pusilla	Scan	
Oocystis pyriformis	Scan	
Pandorina morum	1.861	Scan
Palmella mucosa	5.584	
Pediastrum boryanum	Scan	
Quadrigula closterioides	Scan	
Selenastrum westii	0.233	
Staurastrum paradoxum		Scan
Tetraedron trigonum		Scan
unidentified unicell	0.116	
Chrysophyta (diatoms, chrysophytes)		
Fragilaria crotonensis	Scan	Scan
Gloeobotrys limneticus	Scan	
Melosira granulata	0.349	Scan
Pyrrhophyta (dinoflagellates, cryptomonads)		
Ceratium hirundinella	1.047	1.562
Chroomonas minuta	0.116	Scan
Cyanophyta (blue-green algae)		
Anabaena planktonica	30.943	49.109
Aphanizomenon flos-aquae	657.369	1413.742
Aphanocapsa pulchra	Scan	Scan
Coelosphaerium naegelianum	Scan	
Coelosphaerium kuetzinianum	6.980	
Gomphosphaeria aponina	3.374	1.735
Microcystis aeruginosa	Scan	1.388
Oscillatoria limnetica	0.698	
Oscillatoria tenuis	Scan	10.585
Total Cells Per Sample (count in millions)	708.670	1478.642

NOTE: "Scan" indicates species was observed during preliminary, non-quantitative scan. Many large clumps of dead Microcystis aeruginosa were observed but not counted.

TABLE 3-8. Descriptions of sediment cores taken from Cree Lake canal system.

STATION	APPARENT VISUAL LAYER	EXTENT OF LAYERS (in)	(cm)	REMARKS
SED-1	Surface	19.7	50.0	Entire core consists of decaying plant material.
SED-2	Surface	19.7	50.0	Entire core consists of decaying plant material.
SED-3	Surface	8.5	21.6	Decaying plant material at surface.
	Bottom	3.5	8.9	Fine grained, dark brown sediment on bottom.
SED-4	Surface	19.7	50.0	Entire core consists of decaying plant material.

TABLE 3-9. Results of sediment sample analysis for Cree Lake.

STATION	TP (mg/l)	TKN (mg/l)	VS (mg/kg)
SED-1	78	514	347000
SED-2	73	1009	420000
SED-3	197	719	230000
SED-4	146	652	238000

sediments. The fairly low TP values observed are often encountered under anaerobic conditions where chemical equilibria processes drive the active migration of phosphorus into the water.

Presently, no guidelines exist for evaluating the importance of contaminant levels in aquatic sediments. The only criteria available are standards established by the Environmental Protection Agency that define hazardous wastes. These measures are used to determine the suitability of dredge spoil for disposal in hazardous waste landfills. Contaminant concentrations in aquatic sediments were measured through an Extraction Procedure (EP) toxicity test that simulated the leach potential of contaminants under conditions that might be expected to occur in a landfill. If the magnitude of EP-simulated leaching was greater than the established standards, the material is classified as a hazardous waste. Results of the EP toxicity test performed on the Cree Lake sediment samples indicated that there were no contaminant concentrations above the established standards (Table 3-10) and most of the analytes were below their detection limits.

TABLE 3-10. Results of EP toxicity analysis of Cree Lake sediment composites.

PARAMETER	SED-1 (ppm)	SED-2 (ppm)	SED-3 (ppm)	SED-4 (ppm)	Standard (ppm)
Arsenic	<0.001	<0.001	<0.001	<0.001	5.00
Barium	<0.01	<0.01	<0.01	<0.01	100.00
Cadmium	<0.01	<0.01	<0.01	<0.01	1.00
Chromium	0.09	0.05	0.03	0.04	5.00
Lead	<0.01	<0.01	<0.01	<0.01	5.00
Mercury	<0.001	<0.001	<0.001	<0.001	0.20
Selenium	<0.001	<0.001	<0.001	<0.001	1.00
Silver	<0.01	<0.01	<0.01	<0.01	5.00
Endrin	<0.001	<0.001	<0.001	<0.001	0.02
Lindane	<0.001	<0.001	<0.001	<0.001	0.40
Methoxychlor	<0.001	<0.001	<0.001	<0.001	10.00
Toxaphene	<0.001	<0.001	<0.001	<0.001	0.50
2,4-D	<0.001	<0.001	<0.001	<0.001	10.00
2,4,5-T P	<0.001	<0.001	<0.001	<0.001	1.00

The results of the depth to sediment, probe rejection depth, and sediment thickness measurements taken at Cree Lake near the southeastern inlet are presented in Table 3-11. The channel was shallowest near the culvert and gradually became deeper further into the canal. Thickness determinations indicated that the greatest amount of unconsolidated sediment was found near the middle of the transect. These results were expected because of the loss of velocity (and sediment carrying potential) experienced by water flowing from the culvert into the canal. Materials settle along a continuum in the canals, with the most dense particles dropping out closest to the inlet mouth. The less dense, unconsolidated matter is carried further into the canal system. It is important to note that decomposing plant material tends to be less dense and, therefore, would be expected to travel well into the canal before being deposited.

3.1.5 Bathymetry

Review of the bathymetric data collected for this project indicated that the maximum depth of Cree Lake was 27 feet (8.2 m) as shown in Figure 3-3. The mean depth was 15.7 feet (4.8 m) and the volume was 3.82 X 10^7 cubic feet (1.08 X 10^7 m^3). Comparison of the

TABLE 3-11. Results of the sediment depth measurements taken at Cree Lake.

DISTANCE FROM CULVERT (feet)	(m)	DEPTH TO SEDIMENT (inches)	(cm)	REJECTION DEPTH (inches)	(cm)	SEDIMENT THICKNESS (inches/	cm)
99	30	3.9	10.0	66.9	170.0	63.0	160.0
125	38	13.8	35.0	76.8	195.0	63.0	160.0
150	46	13.8	35.0	84.6	215.0	70.9	180.0
175	53	17.7	45.0	85.8	218.0	68.1	173.0
200	61	23.6	60.0	70.9	180.0	47.2	120.0
225	69	25.6	65.0	72.8	185.0	47.2	120.0
250	76	31.5	80.0	74.8	190.0	43.3	110.0

most recent bathymetric survey and the 1966 Indiana Department of Natural Resources (IDNR) survey indicate that no significant sediment accumulation has occurred in the main body of lake. Because no historical data was obtained for the canal system, detailed determinations of depth loss there were not possible. Visual inspections, however, indicated that the canals had experienced substantial sedimentation in recent years.

The maximum depth of Schockopee Lake was 26 feet (7.9 m), as shown in Figure 3-4. The volume of the lake was 1.00 X 10^7 cubic feet (2.8 X 10^6 $m^{3)}$ and the mean depth was 13.3 feet (4.1 m). Comparison of this survey and the 1961 IDNR survey indicate that no significant sediment accumulation has occurred in the lake.

3.1.6 Aquatic Vegetation

The aquatic vegetation survey documented a wide diversity of macrophytes for both Cree (Table 3-12) and Schockopee Lakes (Table 3-13). The dominant emergent species in Cree Lake were arrow arum (*Peltandra virginica*) and common cattail (*Typha latifolia*). The predominant submergent species throughout this lake were coontail (*Ceratphyllum demersum*), stonewarts (*Chara*), wild celery (*Vallisneria americana*), and American pondweed (*Potamogeton americanus*). The most common floating species along the shores of Cree Lake were the yellow and white water lilies (*Nuphar variegatum* and *Nymphaea ordorata* respectively).

Another smaller yellow lily, identified as *Nuphar microphyllum*, was also observed but not verified. If the identification is accurate, then this sighting would be the first ever recorded in Indiana and could lead to designation of the plant as a state endangered species (Hank Huffman, IDNR, pers. communication). Due to the importance of state and Federal Endangered species efforts, verification should be made before any in-lake restoration actions are implemented. In addition, all lily beds should be re-examined for the presence of this species and, if it is found, steps should be taken to protect the plant from inadvertent damage from boating, fishing, and/or weed eradication activities.

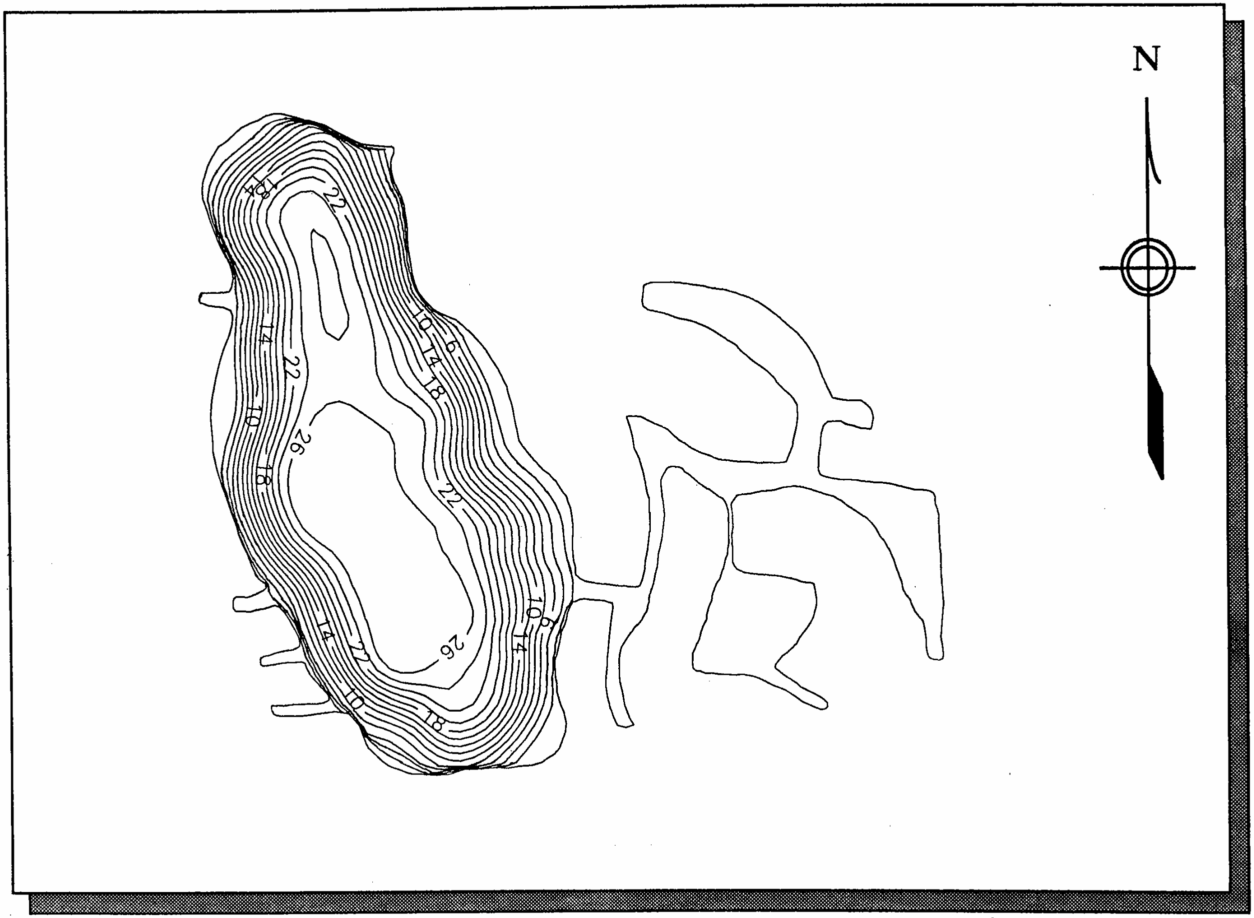

FIGURE 3-3. Bathymetric map of Cree Lake in 1989. Depths are shown in two foot contours.

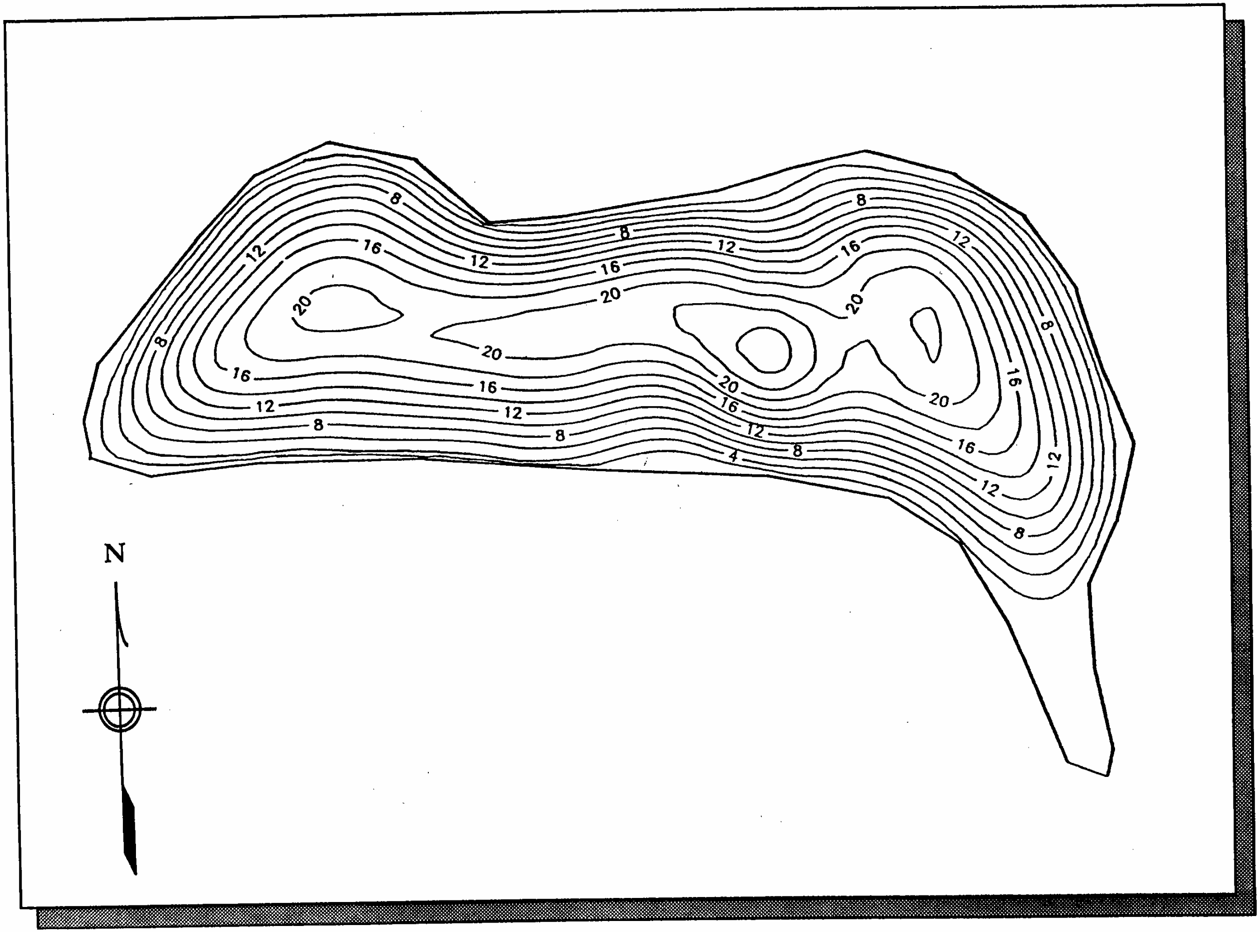

FIGURE 3-4. Bathymetric map of Schockopee Lake in 1989. Depths are shown in two foot contours.

TABLE 3-12. List of macrophyte species found in Cree Lake during the summer of 1989.

COMMON NAME	SCIENTIFIC NAME	HABITAT CLASS
white water lily	*Nymphaea ordorata*	Floating
yellow water lily	*Nuphar variegatum*	Floating
yellow water lily	*Nuphar microphyllum*	Floating
blue-green algae	unknown	Floating
big duckweed	*Spirodela polyrhiza*	Floating
duckweed	*Lemna minor*	Floating
watermeal	*Wolffia columbiana*	Floating
arrow arum	*Peltandra virginica*	Emergent
common cattail	*Typha latifolia*	Emergent
bur reed	*Sparganium chlorocarpum*	Emergent
coontail	*Cerataphyllum demersum*	Submergent
wild celery	*Vallisneria americana*	Submergent
stonewarts	*Chara sp.*	Submergent
American pondweed	*Potamogeton americanus*	Submergent
water milfoil	*Myriophyllum spicatum*	Submergent

TABLE 3-13. List of macrophyte species found in Schockopee Lake during the summer of 1989.

COMMON NAME	SCIENTIFIC NAME	HABITAT CLASS
white water lily	*Nymphaea ordorata*	Floating
yellow water lily	*Nuphar variegatum*	Floating
blue-green algae	unknown	Floating
big duckweed	*Spirodela polyrhiza*	Floating
duckweed	*Lemna minor*	Floating
arrow arum	*Peltandra virginica*	Emergent
common cattail	*Typha latifolia*	Emergent
pickeralweed	*Pontederia cordata*	Emergent
coontail	*Cerataphyllum demersum*	Submergent

In the Cree canal system, the dominant floating species were big duckweed (*Spirodela polyrhiza*), watermeal (*Wolffia columbiana*), duckweed (*Lemna minor*), and two unknown species of blue-green algae present as filamentous mats. Aquatic plant coverage maps for the main body of Cree Lake are presented in Figures 3-5a through 3-5c. Coverage maps for the canal system are presented in Figures 3-6a through 3-6c. Note that although duckweed species were present over the entire surface of the canal system during field investigations, their coverages are not displayed on this map because they would conceal the distribution of other floating macrophytes.

In Schockopee Lake, the predominant emergent species were arrow arum and common cattail. Pickeralweed (*Pontederia cordata*) was also observed along the northern shore of the lake. Coontail was the only submergent macrophyte present. Of the floating species, white and yellow water lilies and unknown filamentous blue-green algae were most common along the shores of the lake. Duckweed and big duckweed dominated the ditch area in the south-east portion of the lake. Aquatic plant coverage maps for Schockopee Lake are presented in Figures 3-7a through 3-7c.

3.1.7 Trophic Index

A BonHomme Eutrophication Index (EI) was calculated for both Cree and Schockopee Lakes. The index combines information about several diverse parameters into a single number intended to describe the degree of lake aging brought on by external inputs. Points are assigned for lake trophic parameters to give scores from 0 to 75, with values near 0 being the least eutrophic. EI values can be used as a basis for establishing and comparing priorities for lake remediation throughout the state. It should be noted, however, that the data used to construct the EI are typically derived from a single sampling event and, therefore, only capture conditions as they existed on a single day in mid-summer. The calculations used to derive the EI valves for this study are presented in Tables 3-14 and 3-15.

The EI values were calculated to be 27 and 44 points for Cree Lake and Schockopee Lake, respectively. Both water bodies are placed in the "Class Two" category within the IDEM Lake Management scheme. Lakes in this category are described as "productive and slowly moving toward senescence." They often support extensive concentrations of macrophytes and/or algae but not at levels that severely impair beneficial uses (e.g., fishing, swimming). Most Indiana lakes fall into this category. It should be noted that IDEM previously derived different EI values for both lakes. The difference is probably explained by the temporally variable nature of physical, chemical, and biological conditions in lakes. The recent dry summers also may have exerted an influence.

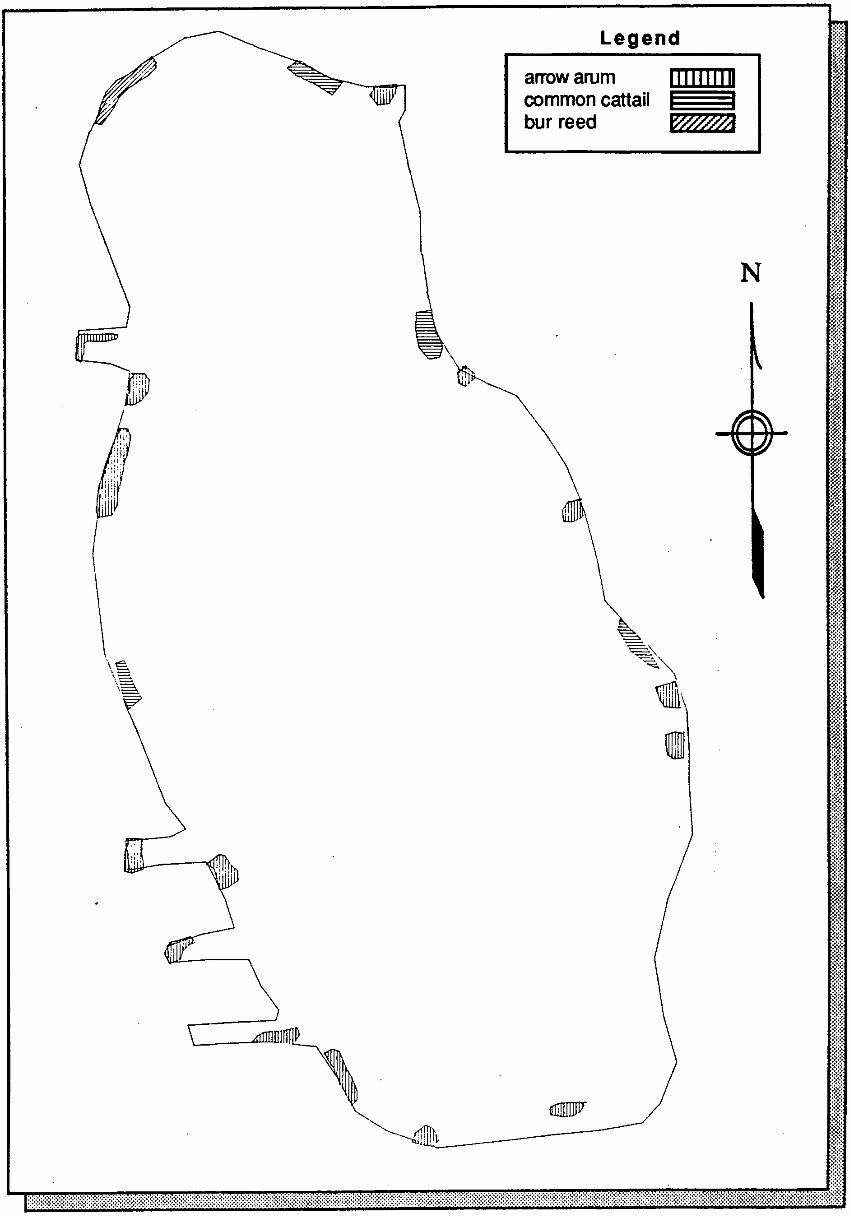

FIGURE 3-5a. Emergent macrophyte distribution in Cree Lake.

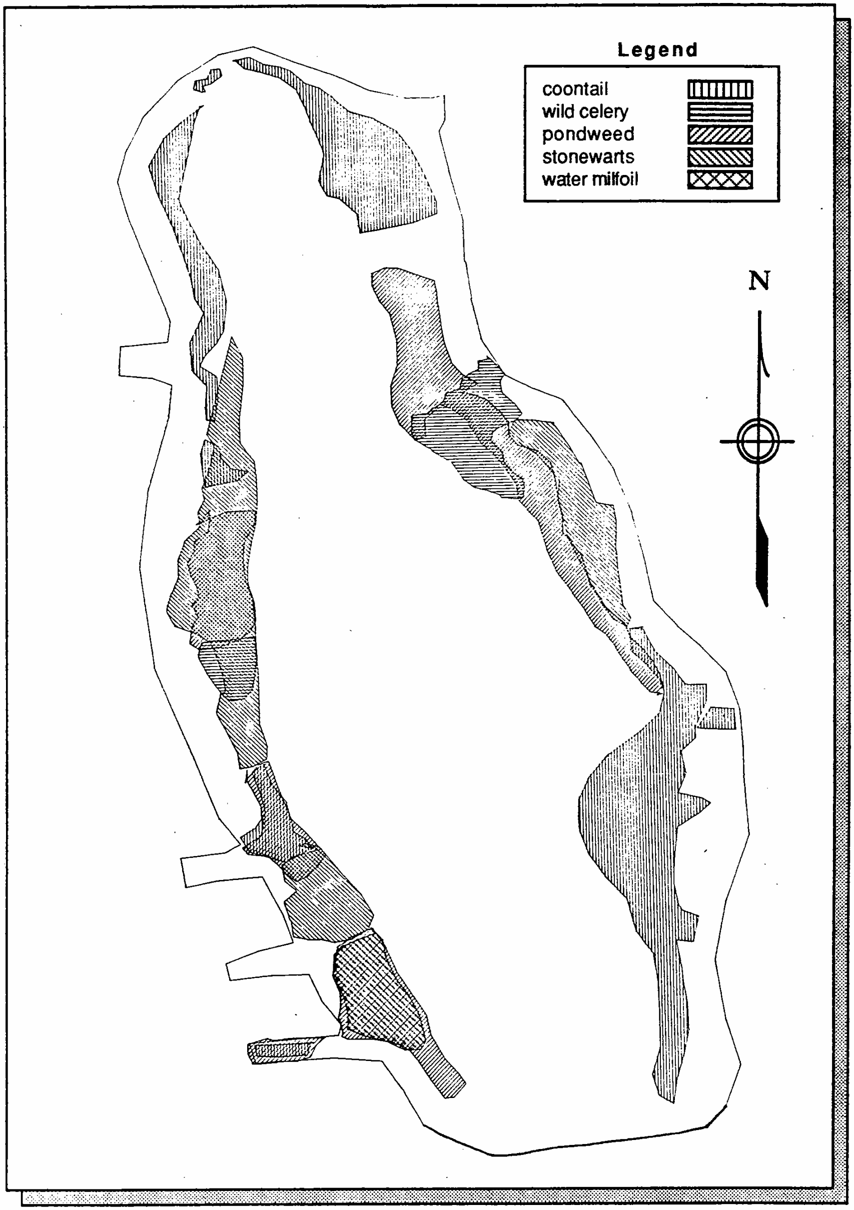

FIGURE 3-5b. Submergent macrophyte distribution in Cree Lake.

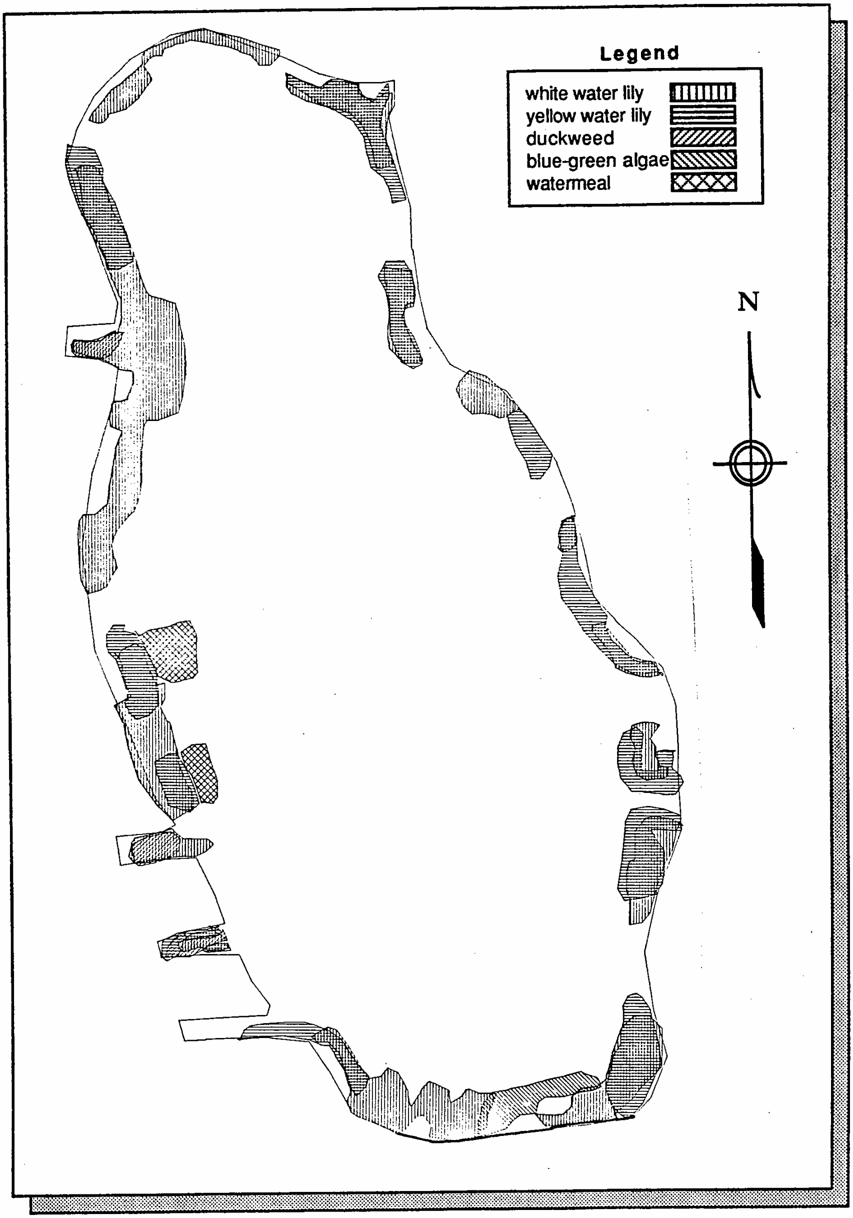

FIGURE 3-5c. Floating macrophyte distribution in Cree Lake.

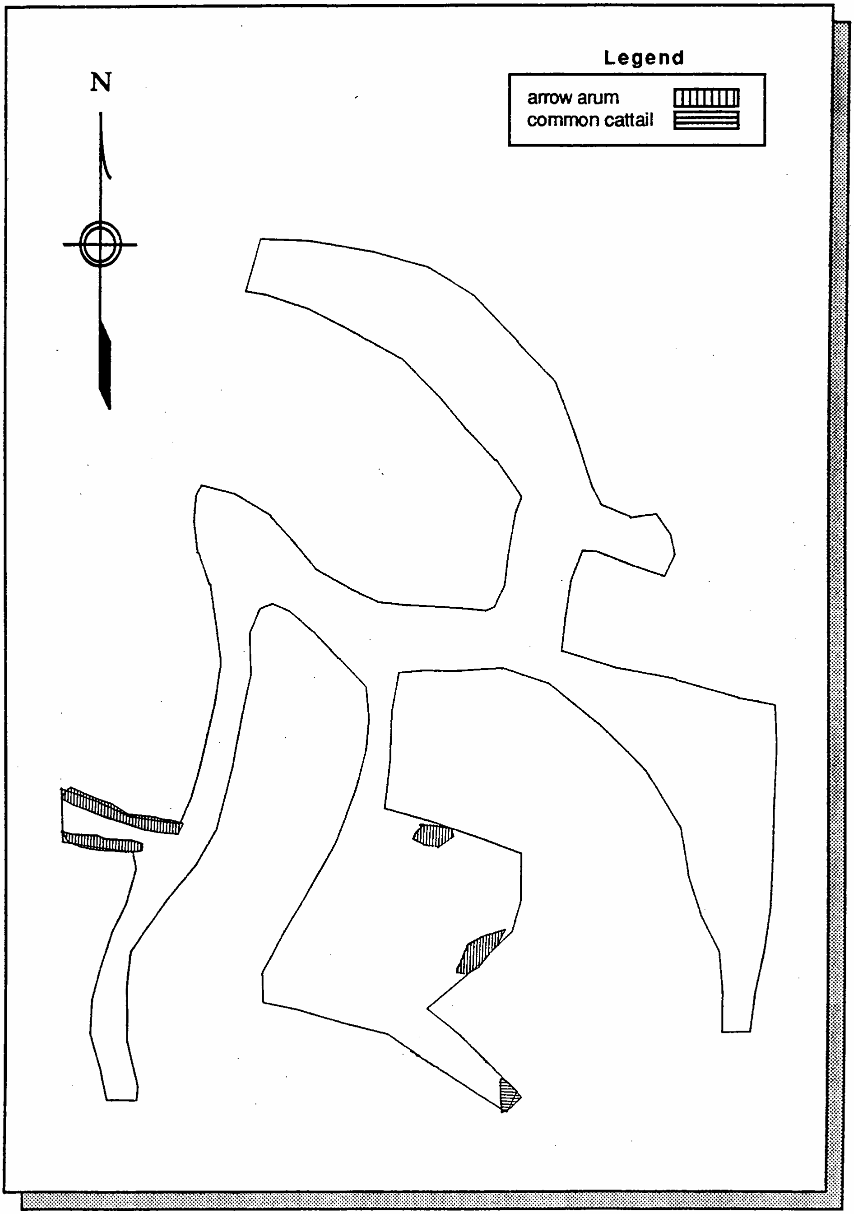

FIGURE 3-6a. Emergent macrophyte distribution in Cree Lake canal system.

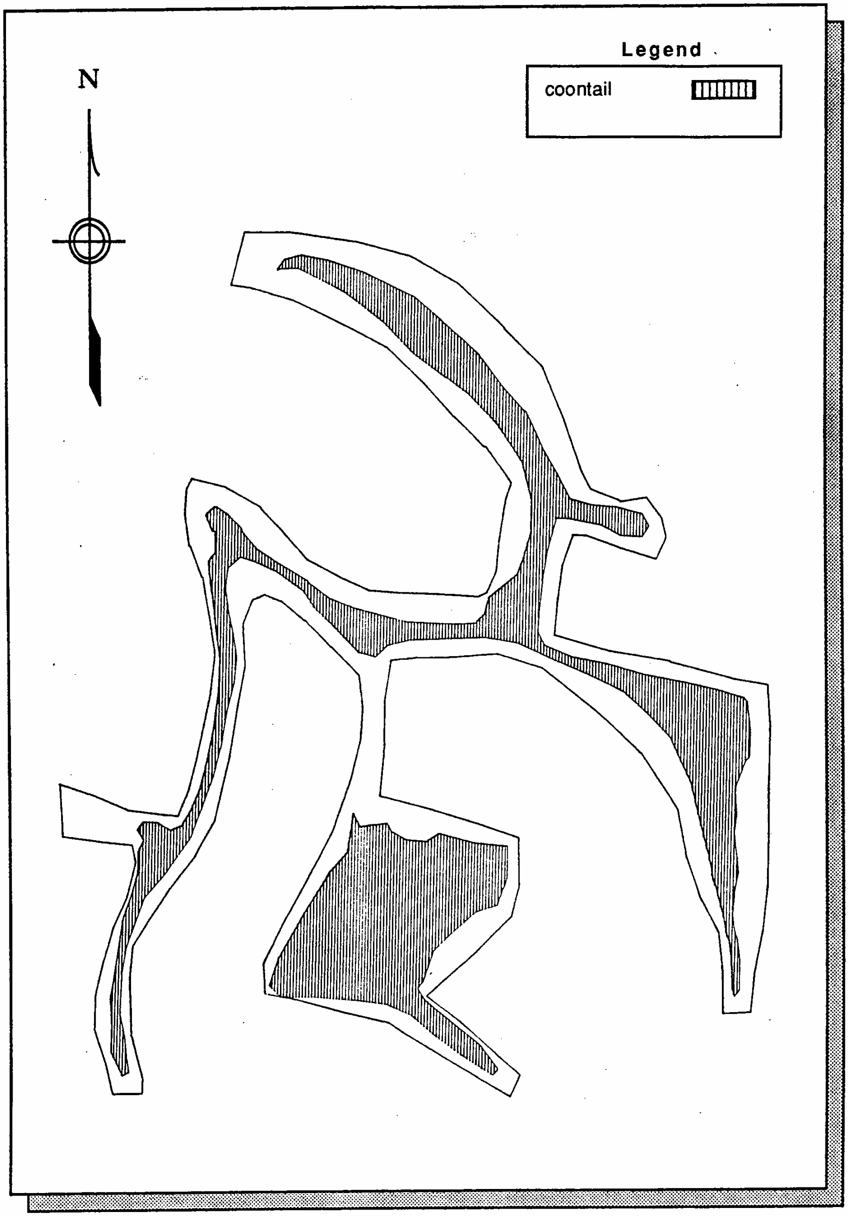

FIGURE 3-6b. Submergent macrophyte distribution in Cree Lake canal system.

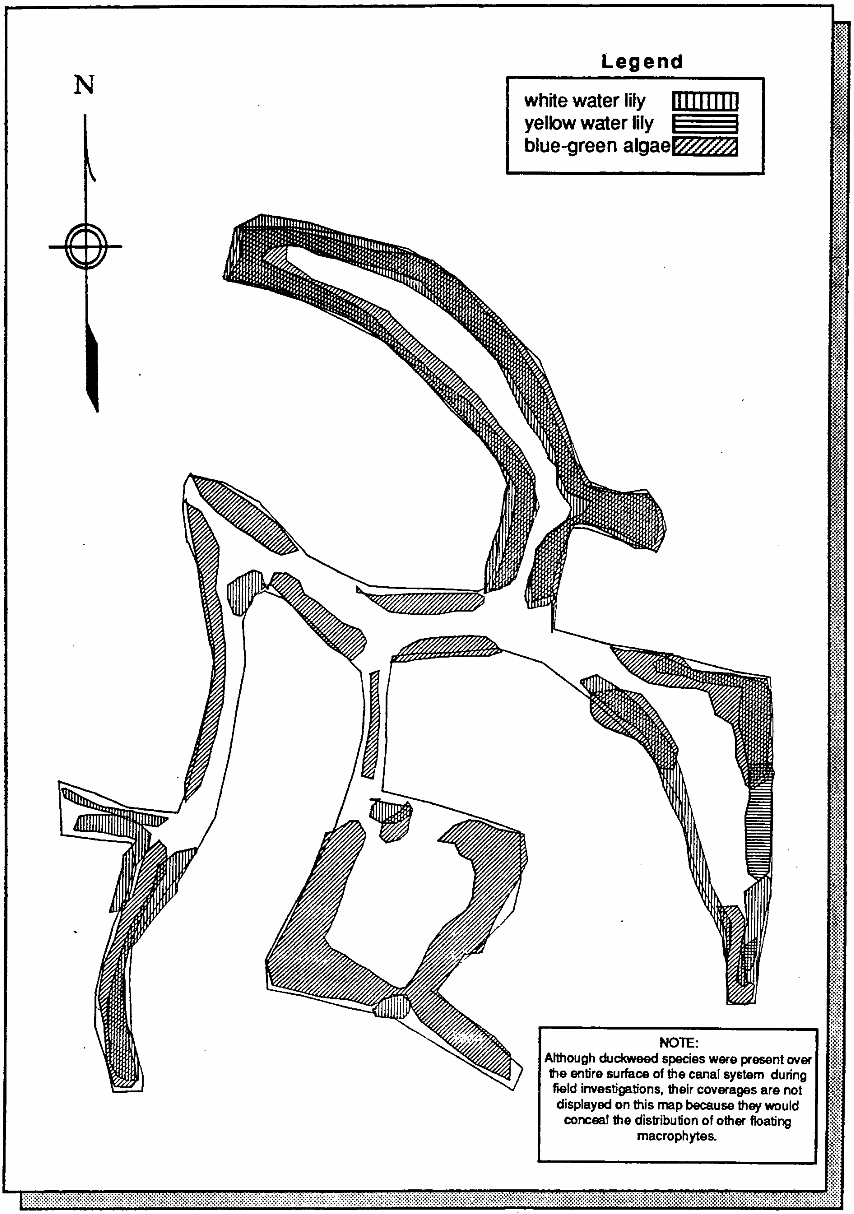

FIGURE 3-6c. Floating macrophyte distribution in Cree Lake canal system.

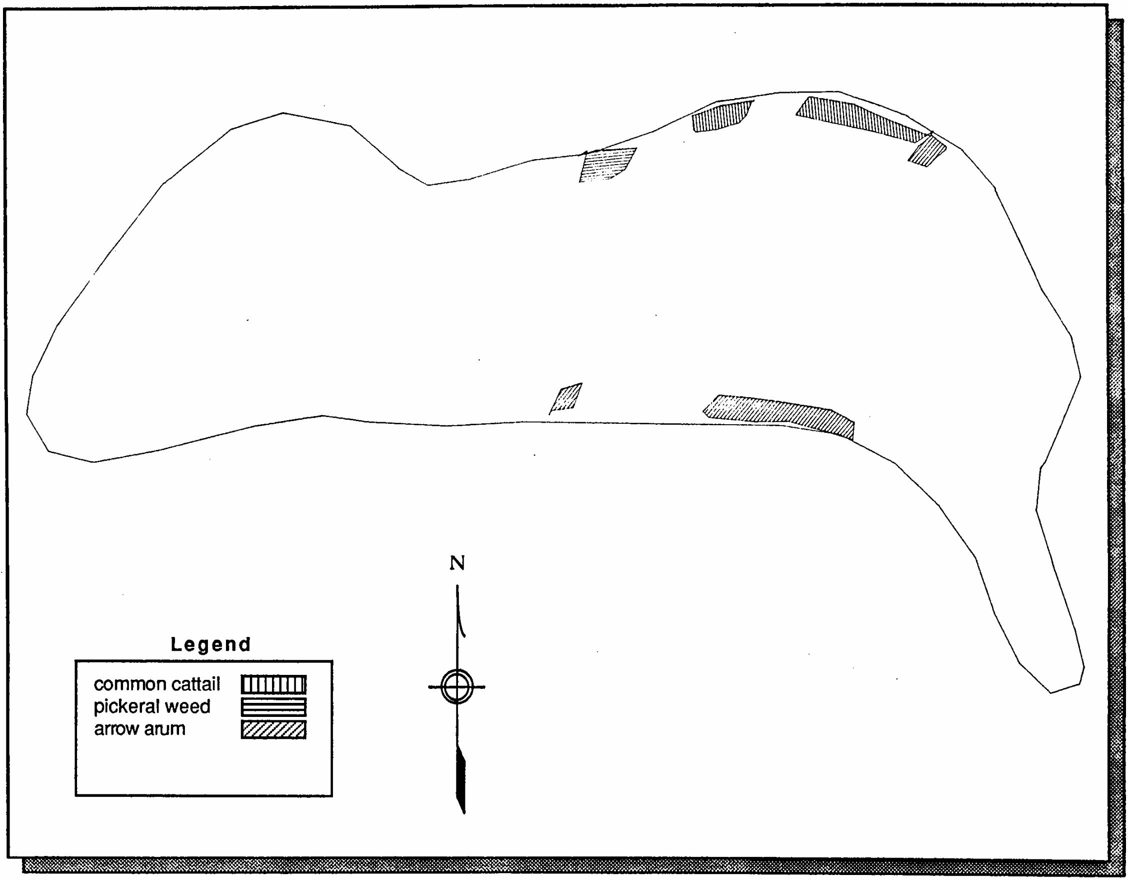

FIGURE 3-7a. Emergent macrophyte distribution in Schockopee Lake.

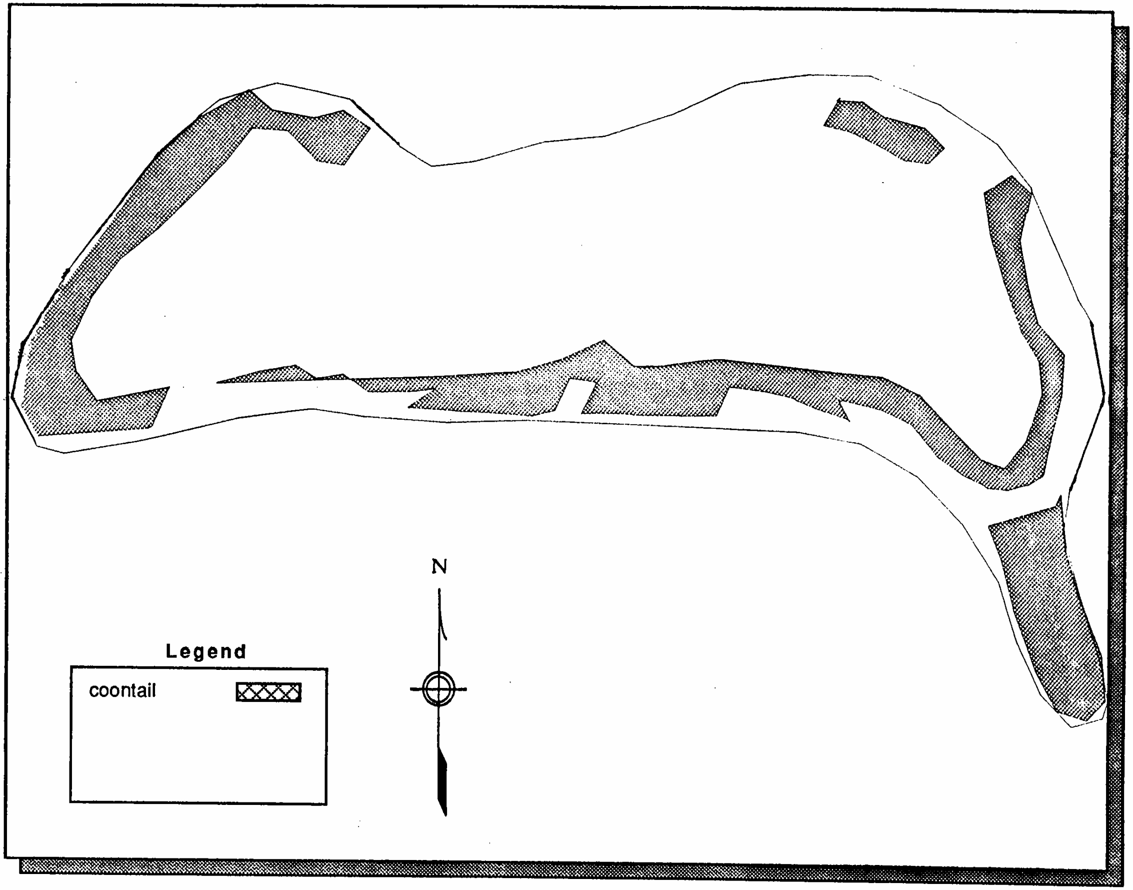

FIGURE 3-7b. Submergent macrophyte distribution in Schockopee Lake.

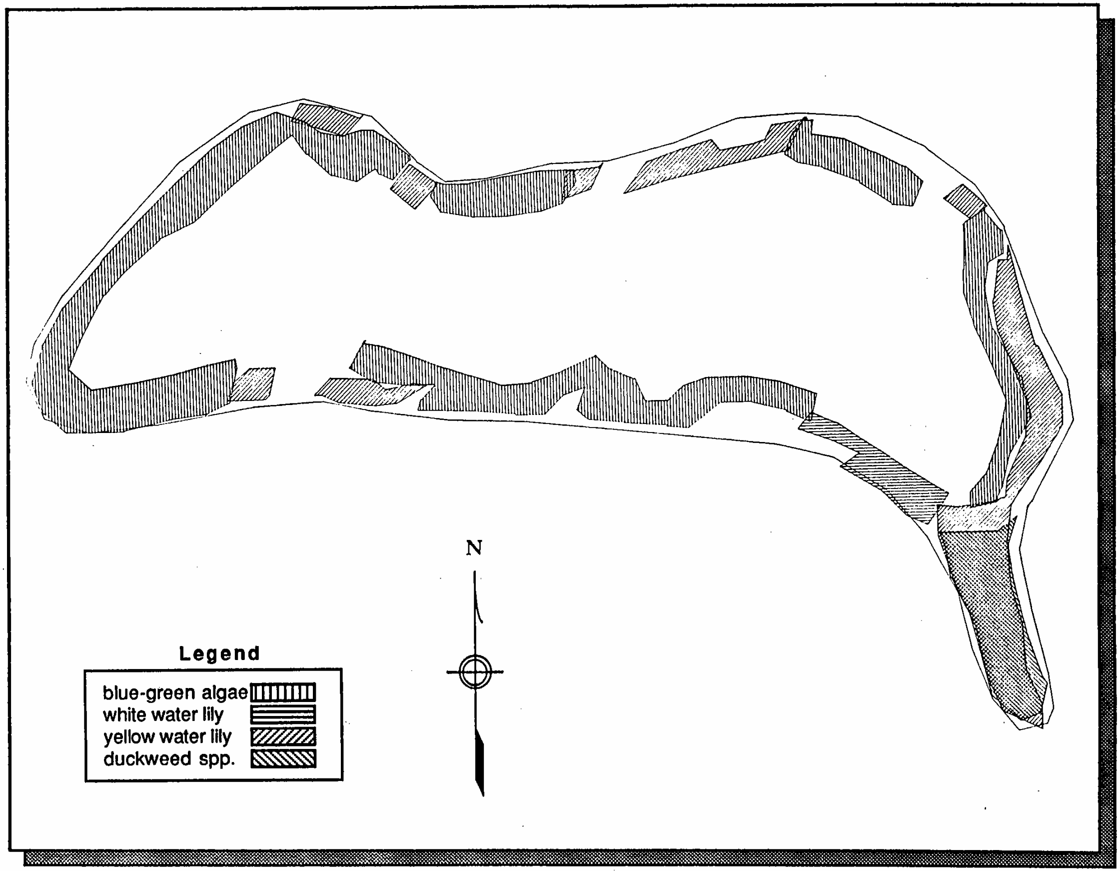

FIGURE 3-7c. Floating macrophyte distribution in Schockopee Lake.

TABLE 3-14. Eutrophication index calculations performed on data collected from Cree Lake on 13 July 1989.

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Total Phosphorus (mg/l)			
1At least 0.03			0
0.04 to 0.05	2		0
0.06 to 0.19	3	X	3
0.20 to 0.99	4		0
Greater than 0.99	5		0
Soluble Phosphorus (mg/l)			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3	X	3
0.20 to 0.99	4		0
1.0 or more	5		0
Organic Nitrogen (mg/l)			
At least 0.50	1		0
0.60 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Nitrate (mg/l)			
At least 0.3	1		0
0.40 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Ammonia (mg/l)			
At least 0.30	1		0
0.40 to 0.50	2		0
0.60 to 0.90	3	X	3
1.0 or more	4		0
Percent oxygen saturation at 5 feet			
114% or less	0	X	0
115% to 119%	1		0
120% to 129%	2		0
130% to 149%	3		0
150% or more	4		0

TABLE 3-14 (continued). **Eutrophication index calculations performed on data collected from Cree Lake on 13 July 1989.**

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Percent of Water Column with at least 0.1 ppm DO			
28% or less	4		0
29% to 49%	3		0
50% to 65%	2	X	2
66% to 75%	1		0
76% to 100%	0		0
Secchi Disk Transparency			
5 feet or less	6		0
greater than 5 feet	0	X	0
Light Transmission at 3 Feet			
0% to 30%	4		0
31% to 50%	3		0
51% to 70%	2	X	2
71% or greater	1		0
Total Plankton from 5 foot Tow (#/ml)			
Less than 500/ml	0	X	0
500/ml to 999/ml	1		0
1000/ml to 1999/ml	2		0
2000/ml to 2999/ml	3		0
3000/ml to 5999/ml	4		0
6000/ml to 9999/ml	5		0
10000/ml or more	10		0
Blue-green dominance	5 additional points	X	5
Total Plankton from Thermocline Tow (#/ml)			
Less than 1000/ml	0	X	0
1000/ml to 1999/ml	1		0
2000/ml to 4999/ml	2		0
5000/ml to 9999/ml	3		0
10000/ml to 19999/ml	4		0
20000/ml to 29999/ml	5		0
30000/ml or more	1		0
Blue-green dominance	5 additional points	X	5
Populations of 100000 or more	5 additional points		0
INDEX VALUE			27

TABLE 3-15. Eutrophication index calculations performed on data collected from Schockopee Lake on 13 July 1989.

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Total Phosphorus (mg/l)			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3		0
0.20 to 0.99	4	X	4
Greater than 0.99	5		0
Soluble Phosphorus (mg/l)			
At least 0.03	1		0
0.04 to 0.05	2		0
0.06 to 0.19	3	X	3
0.20 to 0.99	4		0
1.0 or more	5		0
Organic Nitrogen (mg/l)			
At least 0.50	1		0
0.60 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Nitrate (mg/l)			
At least 0.3	1		0
0.40 to 0.80	2	X	2
0.90 to 1.90	3		0
2.0 or more	4		0
Ammonia (mg/l)			
At least 0.30	1		0
0.40 to 0.50	2		0
0.60 to 0.90	3	X	3
1.0 or more	4		0
Percent oxygen saturation at 5 feet			
114% or less	0	X	0
115% to 119%	1		0
120% to 129%	2		0
130% to 149%	3		0
150% or more	4		0

TABLE 3-15 (continued). **Eutrophication index calculations performed on data collected from Schockopee Lake on 13 July 1989.**

PARAMETER AND RANGE	RANGE VALUES	RANGE OBSERVED	POINT VALUE
Percent of Water Column with at least 0.1 ppm DO			
28% or less	4		0
29% to 49%	3	X	3
50% to 65%	2		0
66% to 75%	1		0
76% to 100%	0		0
Secchi Disk Transparency			
5 feet or less	6	X	6
greater than 5 feet	0		0
Light Transmission at 3 Feet			
0% to 30%	4		0
31% to 50%	3	X	3
51% to 70%	2		0
71% or greater	1		0
Total Plankton from 5 foot Tow (#/ml)			
Less than 500/ml	0		0
500/ml to 999/ml	1		0
1000/ml to 1999/ml	2		0
2000/ml to 2999/ml	3		0
3000/ml to 5999/ml	4		0
6000/ml to 9999/ml	5	X	5
10000/ml or more	10		0
Blue-green dominance	5 additional points	X	5
Total Plankton from Thermocline Tow (#/ml)			
Less than 1000/ml	0		0
1000/ml to 1999/ml	1		0
2000/ml to 4999/ml	2		0
5000/ml to 9999/ml	3	X	3
10000/ml to 19999/ml	4		0
20000/ml to 29999/ml	5		0
30000/ml or more	10		0
Blue-green dominance	5 additional points	X	5
Populations of 100000 or more	5 additional points		0
INDEX VALUE			44

In 1986, IDEM revised the Indiana Lake Classification and Management Plan, parating lakes into distinct "management groups." This categorization was in addition to the "Class Two" distinction, noted above. The management groups were derived using a cluster analysis procedure that compared and grouped Indiana lakes on the basis of EI value, mean depth, and surface area. In the IDEM report and in this study, Cree and Schockopee Lakes were assigned to the "Group VII" management set. This classification generally designates a class of water bodies where water quality problems are not severe enough to warrant extensive restoration measures, and the primary restoration strategy is the limitation of nutrient inputs. Applicable management techniques will be described in Section 4 of this report.

3.2 WATERSHED SURVEY RESULTS

The findings of the watershed survey are presented in this subsection. Topics addressed include climate, hydrology, soils, and land use. It is critical to understand these characteristics because they influence the dynamics of water, sediment, and nutrients associated with the lake. The results of the AGNPS modeling exercise are also addressed because the computer was an important tool for integrating the effects of these factors and interpreting their significance.

Visual observation of the watershed indicated that the wetlands adjacent to the Cree canal system were a potential site for threatened and endangered plant and animal populations. Communications with the Division of Nature Preserves, Indiana Department of Natural Resources revealed that two state listed species have been observed in the proximity of the Cree Lake watershed. The state threatened Eastern massasauga (*Sistrurus catenatus catenatus*) was seen in the wetlands northeast of Cree Lake. The state and Federal endangered bald eagle (*Haliaeetus leucocephalus*) was observed foraging in the watershed within the last 5-10 years. It is worth noting that there is a significant circumneutral bog site bordering the catchment known as the Mud Lake Bog. The remainder of the watershed appeared to be agricultural in nature and no significant problem areas were identified during the reconnaissance visits.

3.2.1 Climate

Climate is often considered a "master variable" in controlling the condition of inland water bodies. It drives the hydrologic cycle, directly governing hydrologic inputs such as rainfall and outputs such as evaporation. It affects soil moisture conditions and plant growth which in turn influence the potential for surface water losses through evapotranspiration and infiltration. Runoff and stream flow, therefore, are also dependent on the weather. Factors to consider when analyzing climate include:

- Type of precipitation
- Timing of precipitation
- Duration of precipitation
- Direction of storm movement
- Temperature
- Solar energy input.

Selected monthly climatic data for the Cree Lake region are listed in Table 3-16. Discussion of the weather characteristics for the area is presented below. Information for this report was produced using data from a computerized weather generator (Nick and Lane, 1988), the Soil Conservation Service (USDA, 1977), and the Weather Atlas of the United States (DOC, 1968).

TABLE 3-16. Selected climatic data for the Cree Lake watershed.

Precip Month	Precip Durat (In)	Max Temp (Hour)	Min Temp (°F)	Solar Radiat (°F)	(Ly/Day)
January	2.47	17.6	33.3	17.3	123.6
February	2.55	16.3	35.4	18.4	195.7
March	2.79	20.8	45.4	26.5	293.2
April	4.03	22.0	58.0	37.0	372.2
May	3.75	17.8	69.9	47.9	467.6
June	3.29	12.0	79.4	58.3	528.3
July	3.61	15.5	84.2	62.6	520.2
August	2.68	13.9	82.0	59.6	467.1
September	2.46	14.5	75.0	53.6	384.2
October	3.24	14.1	63.5	42.9	271.3
November	2.93	16.2	46.8	30.1	157.7
December	1.99	18.0	35.5	20.4	111.1
AVERAGE	2.98	16.6	59.0	39.6	324.4
TOTAL	35.79	198.6			

The climate of Noble County, influenced both by cool Canadian air masses from the north and by humid semitropical air masses from the south, can be generally described as continental, although there is modification from the Great Lakes. Average winter temperatures range between a minimum of 18.7° F (-7.4° C) and a maximum of 34.7° F (1.1° C). Average summer temperatures range between a minimum of 60.2° F (15.7° C) and a maximum of 81.9° F (27.7° C). Relative humidity at noon is usually near 55% in the summer and 65% in the winter. On most nights, however, relative humidity increases to 95-100%. Dew and frosts are common.

Solar radiation ranges between an average minimum of 111 Langleys per day in December and a maximum of 528 Langleys per day in June. The annual mean is 324 Langleys per day. The sun is observed for 58% of the daylight hours, including approximately 37% in December and 72% in July. An average of 77 days are completely clear each year, and 181 days are overcast. The remainder are either partly sunny or partly cloudy.

Precipitation is evenly distributed throughout the year (Figure 3-8), with a monthly average rainfall of 2.98 inches (7.57 cm). Spring and early summer rains generally exceed precipitation levels during the rest of the year and are considered reliable for ensuring excellent crop growing conditions. Average duration of storms is approximately 16.6 hours, with a minimum of 12.0 hours in June and a maximum of 22.0 hours in April. The mean annual rainfall is 35.8 inches (90.9 cm). Annual snowfall averages 27.0 inches (68.6 cm).

Winds are generally out of the southwest at 8 miles per hour in summer, and out of the northwest at 12 miles per hour in winter. Therefore, summer storms traverse the Cree Lake watershed from southwest to northeast and runoff concentrates first from the southwestern sections of the catchment. Winter storms travel from northwest to southeast but often bring snow rather than rain and, thus, runoff concentration is less of an issue. The only damaging winds arise from thunderstorms or tornadoes, although tornadoes are quite rare. Thunderstorms occur about 46 days of the year.

Investigation of precipitation chemistry in this study focused on plant nutrients (i.e.,nitrogen and phosphorus) in an attempt to quantify atmospheric loading of these factors. Although information on the subject was scarce, data were found for two monitoring stations within a reasonable distance of Cree and Schockopee Lakes: Benton Harbor, Michigan and Put-in Bay, Ohio. Interpolated averages were found for total phosphorus (0.07 mg/l), nitrate (0.45 mg/l), and ammonia (1.18 mg/l). Data were deemed unreliable for total nitrogen.

Combining these averages with annual atmospheric water loading yielded estimates for atmospheric nutrient loading. Annual atmospheric loadings to Cree and Schockopee Lakes were calculated to be 33.0 lbs (15.0 kg) and 11.9 lbs (5.4 kg) of total phosphorus, 212.3 lbs (96.3 kg) and 76.7 lbs (34.8 kg) of nitrate-nitrogen, and 556.8 lbs (252.5 kg) and 201.1 lbs (91.2 kg) of ammonia-nitrogen, respectively.

It should be noted, however, that although these figures formed the basis for assessing atmospheric nutrient loading, the supporting data were gathered at considerable distances from both Cree and Schockopee Lakes, and that a large degree of uncertainty accompanies them. In particular, phosphorus concentrations in rainfall may be considerably

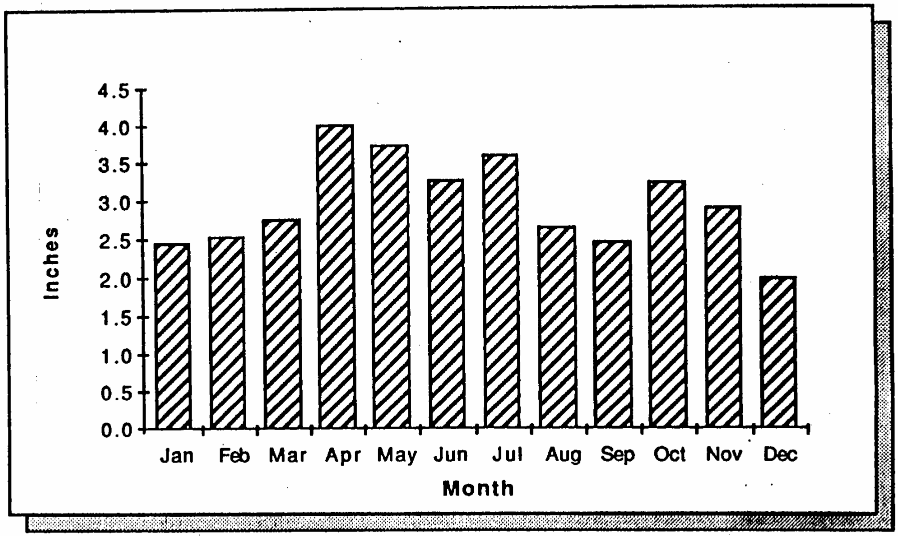

FIGURE 3-8. Monthly distribution of precipitation in the Cree Lake watershed.

higher in Noble County than indicated by these figures. Intensive row crop agriculture is practiced in many areas of the County and tends to contribute large amounts of particle-bound phosphorus to the atmosphere in the form of dust. Such areas generally experience increased phosphorus levels in precipitation.

3.2.2 Hydrology

Another "master variable" controlling the condition of water bodies is the physical layout of the drainage basin. The general topographic attributes of the catchment area influence the behavior of water once it reaches the ground. In conjunction with climate, hydrologic qualities affect runoff volume (i.e, mass input), velocity (i.e., erosional capacity), and timing (i.e., flood potential). Important aspects of a watershed investigation include consideration of the following features:

- Basin area
- Catchment shape
- Slope
- Geographic orientation
- Drainage pattern.

Characterization of hydrologic features focused on two types of analyses: (1) a general description of watershed morphological attributes, and (2) calculation of an approximate mass-balance water budget. Appropriate discussion of the components of each analysis are included.

The Cree Lake watershed covers approximately 3490 acres (1413 ha) and is irregularly shaped (Figure 3-9). Its longitudinal axis runs from southwest to northeast lending an appearance of "tilt" to the catchment outline. Its gravitational center is situated almost 2.5 miles (1.6 km) southeast of the Cree lake outlet. The perimeter of the watershed is roughly 14.6 miles (23.5 km). The most distant point of the basin lies at its eastern tip, close to the intersection of the 1200 East Road and the 1000 North Road. This point is approximately 3.4 miles (5.4 km) from the lake outlet and constitutes the endpoint of the watershed's "axial length." The average width of the basin, defined as the ratio of catchment area to axial length, is 1.31 miles (2.1 km). These and other key morphological parameters are presented in Table 3-17. Discussion of the significance of pertinent indices follows.

The slope of a drainage basin has an important and complex role influencing infiltration, runoff, soil moisture, and groundwater contribution to stream flow. It is one of the major factors governing the time required by overland flow to reach channels where it is quickly transferred downstream (i.e, time of concentration). Steeper slopes generally increase runoff velocity, thereby decreasing time of concentration. Elevated runoff velocity is also accompanied by diminished infiltration and enhanced erosional capacity. The Cree/Schockopee watershed has an average slope 4.5%, reflecting the relatively flat topography of the region. The minimum slope, 1.1%, occurs approximately 1 mile northeast of Wayne

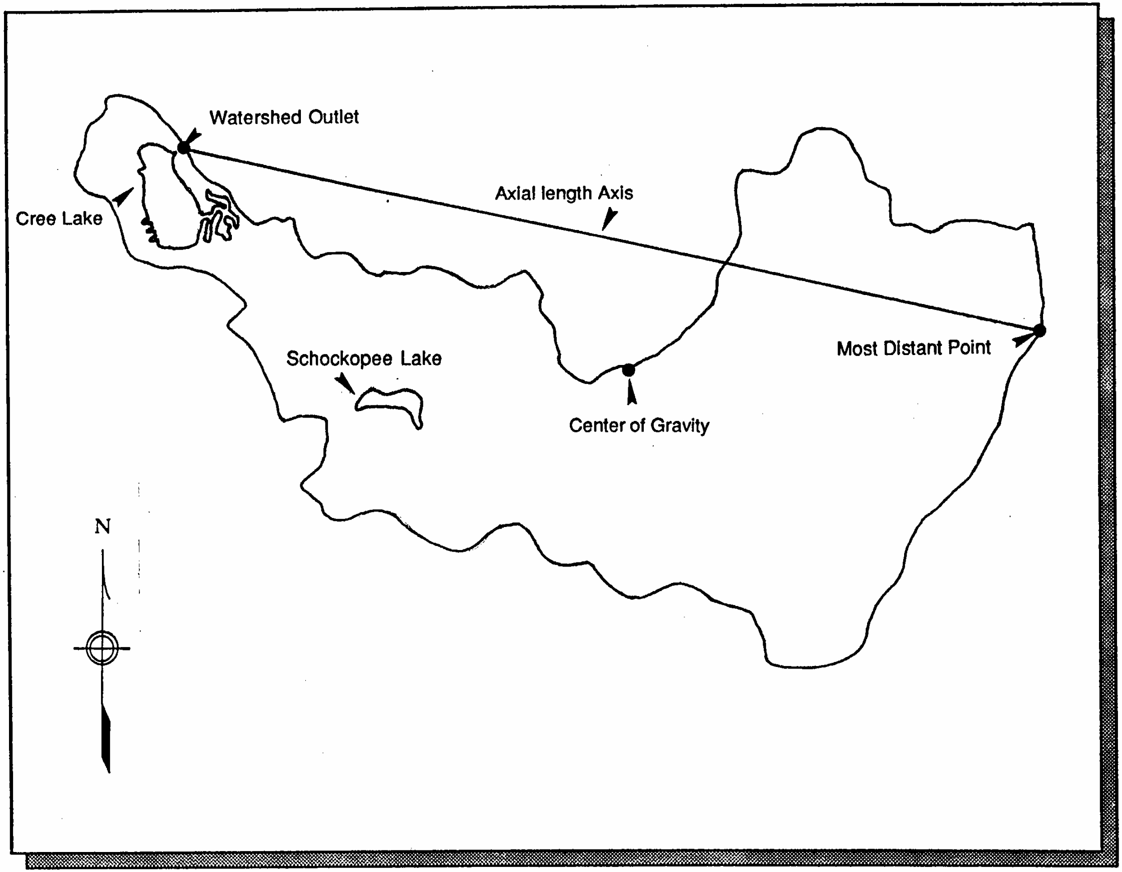

FIGURE 3-9. Outline and pertinent features of the Cree Lake watershed.

TABLE 3-17. Morphological features of the Cree Lake watershed.

ATTRIBUTE	TRADITIONAL VALUE	METRIC VALUE
Area	3490.0 acres	1413.0 ha
Perimeter	14.6 miles	23.5 km
Axial Length	3.4 miles	3.4 km
Average Width	1.3 miles	2.1 km
Average Slope	4.5 %	same
Minimum Slope	1.1 %	same
Maximum Slope	8.7 %	same
Form Factor	0.37 (unitless)	same
Compactness Coeff.	1.76 (unitless)	same
Eccentricity	2.21 (unitless)	same
Drainage Density	1.67 miles/mile^2	1.04 km/km^2

Center. The maximum slope, 8.7%, occurs just north of Schockopee Lake along the border of the watershed and is manifested in an area of 70% forested land. The elevation of the basin ranges from 947 feet (287 m) at Cree lake to 1050 feet (320 m) near the southern tip of the watershed.

Another consideration in characterizing the hydrologic components of the Cree Lake watershed is basin orientation. Orientation, often called "aspect", refers to the compass direction toward which most of the slopes in the catchment face. The basin orientation in the Cree Lake watershed is divided into two directions. Since Schockopee Lake is situated west of its drainage area, most slopes face west. Likewise, because Cree Lake is situated northwest of Schockopee Lake, most slopes between the two lakes face north-westward. This orientation is important, especially in winter, because snow on these slopes is not exposed to the most direct angle of solar incidence and, therefore, does not melt as quickly. Snow cover tends to build up in these areas, storing a considerable amount of moisture until early spring thaws. When snow melt does occur, the stored water is released, emulating the effects of a large rainfall event developing over a relatively short time. Higher stream flows can be expected in the early spring.

The shape of a drainage basin governs the rate at which runoff is supplied to the catchment's main water body following a precipitation event. Although it is difficult to adequately express shapes by using numerical indices, three such measures were calculated for the Cree/Schockopee watershed: (1) form factor, (2) compactness coefficient, and (3) eccentricity. The form factor is an indicator of the relative elongation of the catchment and is calculated as the ratio of average width to axial length. Basins with form factors that approach 0 are said to be non-uniform and elongated. This type of watershed is not likely to have intense or lengthy rainfall over its entire extent at any one time. Runoff, therefore, tends to reach streams and lakes in pulses rather than simultaneously from all points in the basin. Thus, watersheds with form factors near 0 are usually not prone to high flood peaks. The Cree/Schockopee watershed has a form factor of 0.37 and, using this criteria alone, normally would be classified as elongated and unlikely to experience high flood peaks.

The second shape index estimated for the basin was the compactness coefficient (CC). The CC indicates the degree of uniform shape by comparing the perimeter of the watershed with the perimeter of a circle of equal area. Catchments with CC values that approach 1.0 are nearly circular while those with CC values that diverge from 1.0 in either direction are more complex. Circular (i.e., uniform) watersheds tend to contribute runoff simultaneously and, thus, are also prone to elevated flood peaks resulting from intense or lengthy rainfall events. The Cree/Schockopee catchment has a CC value of 1.76, indicating a somewhat non-circular shape. This finding is due to the "tobacco pipe" shaped appearance of the watershed.

The third shape index used in this study was watershed eccentricity, a measure relating watershed shape to that of an ellipse. Again, the premise is that flood peaks are higher in rounded catchments than in elongated ones. Eccentricity values that approach 0.0 indicate a rounded shape and, thus, are usually associated with high flood peaks. Conversely, values that approach infinity are associated with low flood peaks. In empirical studies of uniform storms covering an entire watershed, this index has been found to be more accurate than either the form factor or the compactness coefficient. The Cree/Schockopee basin has an eccentricity value of 2.21, indicating moderately low flood peak potential.

Another important characteristic of any watershed is the arrangement of the streams that drain it. The efficiency of the drainage system and, therefore, the characteristics of flood peaks are directly dependent on this attribute. Generally, if a basin is well-drained and the length of overland flow is short, surface runoff concentrates rapidly and contributes to a high flood peak. Average flows are usually low in such systems. One measure of drainage efficiency used in this study is termed "drainage density." Being the ratio of total length of perennial channels to total watershed area, this index provides an indication of stream coverage within a basin. The Cree/Schockopee watershed has a drainage density of 1.67 miles/square mile (1.04 km/km^2) and, using this criteria alone, would be considered well-drained and prone to flash flood flows. This tendency is mitigated somewhat by long overland flow (not computed) and deep, infiltratable soils (Section 3.2.3). The pattern of the drainage network can be described as dendritic.

Using the climatic and hydrologic data discussed above, separate annual water budgets were computed for Cree Lake and Schockopee Lake. Water budget components included information on inputs (e.g., direct rainfall, runoff, and groundwater inflow) and outputs (e.g., evaporation, overflow, and leakage). These components are summarized in Tables 3-18 and 3-19.

TABLE 3-18. Components of the Cree Lake water budget.

ANNUALIZED RAW DATA:

ATTRIBUTE	TRADITIONAL VALUE	METRIC VALUE
Watershed Area	664 acres	269 ha
Lake Surface Area	58 acres	23.5 ha
Rainfall	35.8 inches	90.9 cm
Runoff	9.9 inches	25.2 cm
Pan Evaporation (raw)	41.3 inches	104.9 cm
Pan Coefficient	0.77 inches	1.9 cm
Pan Evaporation (adjusted)	31.6 inches	80.3 cm
Potential Evapotranspiration	34.6 inches	88.0 cm

ANNUALIZED WATER BUDGET DATA:

INPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Rainfall	7.55×10^6 cubic feet	2.14×10^5 m^3
Runoff	2.18×10^7 cubic feet	6.17×10^5 m^3
Groundwater)[a]	0.00×10^1 cubic feet	0.00×10^1 m^3
Outflow from Schockopee Lake	1.01×10^8 cubic feet	2.86×10^6 m^3
TOTAL INPUTS	1.30×10^8 cubic feet	3.68×10^6 m^3

OUTPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Evaporation (adjust)	6.64×10^6 cubic feet	1.88×10^5 m^3
Lake Overflow[b]	1.24×10^8 cubic feet	3.50×10^6 m^3
Groundwater[a]	0.00 cubic feet	0.00 m^3
TOTAL OUTPUTS	1.30×10^8 cubic feet	3.68×10^6 m^3

HYDRAULIC RETENTION DATA:

PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Lake Volume	3.82×10^7 cubic feet	1.08×10^6 m^3
Inflow Volume	1.31×10^8 cubic feet	3.71×10^6 m^3
Hydraulic Retention	0.29 years	same

[a]Assumed to be 0 due to unavailability of data.

[b]Calculated as the residual of (inputs - evaporation).

TABLE 3-19. **Components of the Schockopee Lake water budget.**

ANNUALIZED RAW DATA:

ATTRIBUTE	TRADITIONAL VALUE	METRIC VALUE
Watershed Basin	2826 acres	1144 ha
Lake Surface Area	21 acres	8.5 ha
Rainfall	35.8 inches	90.9 cm
Runoff	9.9 inches	25.1 cm
Pan Evaporation (raw)	41.3 inches	104.9 cm
Pan Coefficient	0.77 inches	1.9 cm
Pan Evaporation (adjusted)	31.6 inches	80.3 cm
Potential Evapotranspiration	34.6 inches	88.0 cm

ANNUALIZED WATER BUDGET DATA:

INPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Rainfall	2.73×10^6 cubic feet	7.73×10^4 m^3
Runoff	1.01×10^8 cubic feet	2.86×10^6 m^3
Groundwater[a]	0.00^1 cubic feet	0.00×10^1 m^3
TOTAL INPUTS	1.04×10^8 cubic feet	2.93×10^6 m^3

OUTPUT PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Evaporation (adjust)	2.41×10^6 cubic feet	6.83×10^4 m^3
Lake Overflow[b]	1.02×10^8 cubic feet	2.87×10^6 m^3
Groundwater[a]	0.00 cubic feet	0.00 m^3
TOTAL OUTPUTS	1.04×10^8 cubic feet	2.93×10^6 m^3

HYDRAULIC RETENTION DATA:

PARAMETER	TRADITIONAL VALUE	METRIC VALUE
Lake Volume	1.00×10^7 cubic feet	2.83×10^5 m^3
Inflow Volume	1.04×10^8 cubic feet	2.95×10^6 m^3
Hydraulic Retention	0.09 years	same

[a]Assumed to be 0 due to unavailability of data.
[b]Calculated as the residual of (inputs - evaporation).

The total calculated volume of water input to Cree Lake was 1.31 X 10^8 cubic feet (3.71 X 10^6 m^3). Of this amount, 77.5% was attributed to outflow form Schockopee Lake, 16.7% was attributed to runoff from the catchment (including stream flow) and 5.8% was attributed to direct rainfall on the lake surface. Of the outputs, lake overflow constituted 95% of the total, while evaporation accounted for 5%. Hydraulic retention time, the ratio of lake volume to inflow volume, was estimated to be 0.29 years, indicating a rapid turnover of water in Cree Lake. Retention times of less than 1 year are fairly common for lakes in the northeastern part of the state.

The total calculated volume of water input to Schockopee Lake was 1.04 X 10^8 cubic feet (2.95 X 10^6 m^3). Of this amount, 97.2% was attributed to runoff from the catchment (including stream flow) and 2.8% was attributed to direct rainfall on the lake surface. Of the outputs, lake overflow constituted 98% of the total, while evaporation accounted for 2%. Hydraulic retention time, the ratio of lake volume to inflow volume, was estimated to be 0.10 years, indicating a rapid turnover of water in Schockopee Lake. Again, retention times of less than 1 year are fairly common for lakes in the northeastern part of the state.

An additional component of water resource study is potential evapotranspiration (PET). Used as a measure of the maximum possible evaporation through the soil and vascular plants, analysis of PET gives researchers an indication of water losses from the surface flow regime. On a practical level, calculation of this parameter forms the basis of determining local crop suitability, irrigation requirements, and reservoir design needs. An important subtraction of water from a drainage basin, evapotranspiration dominates the water balance and controls many non-surface phenomena including soil moisture content and groundwater recharge.

Potential evapotranspiration in the Cree Lake watershed was calculated at 34.6 inches (88.0 cm) per year, approximately one inch less than the annual rainfall. Actual evapotranspiration was, of course, much smaller than this estimate, as evidenced by the 9.9 inches (25.1 cm) of annual runoff in the basin. True evapotranspiration, if calculated as a percentage of the residual of rainfall minus runoff (i.e., infiltration), was probably less than 25.9 inches (65.8 cm) and limited by soil and climatic conditions. For example, in some soils, moisture percolates rapidly to the water table and is incorporated in groundwater below the reach of plants and other evaporative mechanisms. Climate exerts an influence both during rainy and dry periods, where there is alternately too much or too little water to supply the removal process. Though not a direct surrogate for true evapotranspiration, PET indicates the magnitude of potential water losses, given a uniform and non-limited water reserve. The high PET value for Cree Lake was not considered unusual.

3.2.3 Soils

The soils in Noble County formed from glacial till, glacial outwash, alluvium, and organic material as the area was covered several times during successive ice-ages. The glacial drift, till, and outwash deposits in the county range in depth from 200 feet in the southwest to 450 feet in the northeast (Wayne, 1956). Cree and Schockopee Lakes lie in an area of deep glacial deposits. Although Noble County contains 8 different soil associations (i.e., distinct proportional patterns of soil types), the Cree Lake watershed is almost entirely comprised of only three. These associations are:

Miami-Riddles-Brookston association: These soils are highly variable within the watershed, ranging from well-drained to very poorly-drained, nearly level to moderately steep. They are deep soils that have a moderately fine textured subsoil and are found primarily on uplands. These soils support crops and pasture.

Houghton-Edwards-Adrian association: These soils are very poorly-drained, nearly level mucks that are deep or moderately-deep over marl or sand and gravel. They are found primarily in depressions or outwash plains. Drained areas of this association are used mostly for crops while undrained areas are mostly under wetland plant cover.

Morley-Blount association: These soils are well-drained to somewhat poorly-drained, nearly level to moderately sloping assemblages. They are deep soils that have a moderately fine textured subsoil and are found primarily on uplands. This association is used mostly for crops.

It should be noted that grouping soils into associations is helpful only for broad, interpretative purposes. The soils in any one association ordinarily differ in slope, depth, stoniness, drainage, and other characteristics that affect their management.

Highly erodible soils, as defined by the Noble County Soil and Water Conservation District (NCSWCD, 1987), are quite common in the Cree Lake watershed. Nearly seven-eighths of the basin experiences extensive sheet, rill, and gully erosion as depicted in Figure 3-10. In Noble County, annual sediment losses due to all sources of erosion have been estimated to be as high as 13.1 tons/acre (29361 kg/ha), but average 11.1 tons/acre (24878 kg/ha). This condition is not only damaging to crops and agricultural production, but also holds serious implications for water resource management. Since approximately 20% of the erosional load (i.e., 338,000 tons, county-wide) is deposited in waterways each year, it is clear that Cree and Schockopee Lakes could be at risk from sedimentation.

3.2.4 Land Use

One of the most influential factors governing the longevity and quality of a surface water body is the nature of land use in the drainage basin. Land use categorization within the Cree/Schockopee watershed was critical in determining input parameters for the AGNPS model. The sixteen different land use categories and corresponding areal coverages are listed in Table 3-20. A color land use map is presented in Figure 3-11.

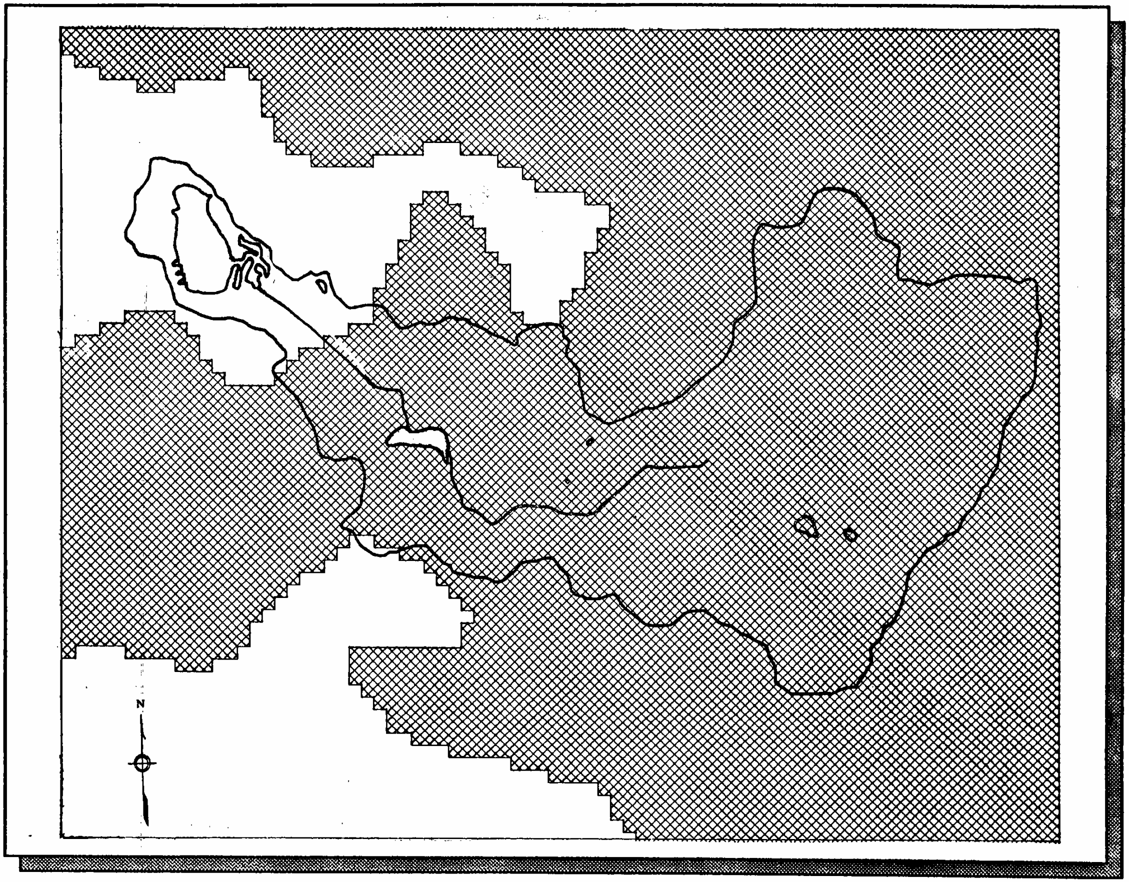

FIGURE 3-10. Erodible soil coverages with the Cree Lake watershed.

TABLE 3-20. Land use areas/percentages for the Cree Lake watershed.

CATEGORY	WATERSHED AREA (acre)	(ha)	WATERSHED PERCENT
Water	97.8	39.6	2.6
Wetlands	91.9	37.2	2.4
Forest	650.8	263.5	17.3
Open	287.5	116.4	7.6
Pasture	76.9	31.1	2.0
Row Crops	1945.7	787.7	51.7
Non Row Crops	323.9	131.1	8.6
Orchard	17.8	7.2	0.5
Feedlot	0.0	0.0	0.0
Low Density Residential	166.5	67.4	4.4
Medium Density Residential	87.8	35.5	2.3
High Density Residential	6.2	2.5	0.2
Commercial	6.1	2.4	0.2
Institutional	5.2	2.1	0.1
Bare Ground	0.0	0.0	0.0
Non-categorized	0.4	0.2	0.1
TOTALS	3764.5	1523.9	100.0

The primary land use within the Cree Lake watershed was row crop agriculture, accounting for 51.7% of the total area. Blocks of row crops were dispersed fairly uniformly throughout the watershed, although the area east of the lakes contained the highest densities of agricultural property. Forested land constituted 17.3% of the watershed and, though present throughout the basin, the majority was located directly east and south of Cree Lake and around the perimeter of Schockopee Lake.

The three residential use categories cumulatively accounted for 6.9% of the area and were distributed with the largest concentrations occurring directly west of Cree Lake along 1100 North Road. Although it comprises a relatively small percentage of the total watershed, the proximity of the largest population concentrations to the lakes makes their impact a significant one. Increased lawn fertilizer runoff, septic and sewer infiltration, and loss of lake-associated wetlands are characteristic of near-shore residential communities.

Wetlands comprised 2.4% of the watershed, a relatively small amount of the total acreage. Their existence, however, is extremely important from an ecological standpoint, and these areas should be protected from alterations and/or destruction. The wetlands

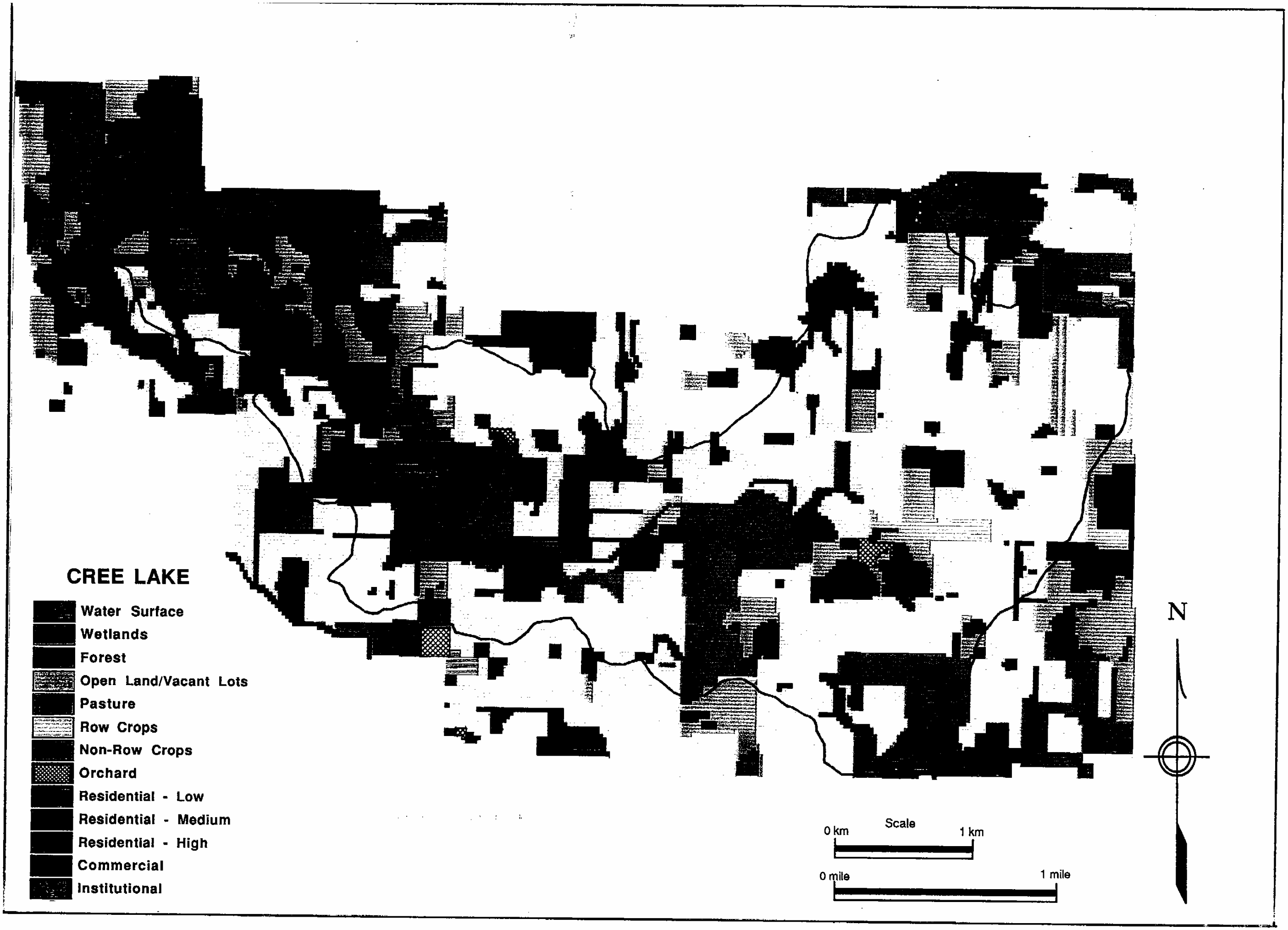

FIGURE 3-11. Land use coverages in the Cree Lake watershed.

existing around both lakes serve as sediment and pollution controls. Wetland vegetation retards the movement of pollutants, acting both as a physical filter and as a mechanism for reducing runoff velocity, allowing sediments and soil-bound contaminants to settle out of surface runoff. In addition to functioning as natural settling ponds, wetlands often remove nutrients and other pollutants from the system by incorporating them into plant biomass. The wetlands existing around Cree and Schockopee Lakes, and their tributaries, are undoubtably benefiting the water bodies.

3.2.5 Modeling Results

The AGNPS model requires the user to divide watersheds into grids of equal sized units, called "cells" (Figure 3-12). Individual cells can be quartered (i.e., divided into 4 equal sub-cells) up to 3 times, if necessary, based on land use, topographical, or soil features. Cells are numbered consecutively from 1, beginning at the northwest corner of the watershed and proceeding from west to east until the end of a row of cells is reached. The count continues then moves down 1 row and again proceeds from west to east. The process is repeated until all cells are assigned a number. Sub-cells are similarly numbered from the northwest, proceeding west to east, yet for accounting purposes, sub-cells retain the designation of their "parent" cells. For instance, if a cell #2 in a given watershed is quartered, it would be assigned sub-cells 2-100, 2-200, 2-300, and 2-400. Similarly, if subcell 2-300 is quartered, it would be assigned sub-sub-cells 2-310, 2-320, 2-330, and 2-340. Carrying this logic out to its farthest extent, if sub-sub-cell 2-310 is quartered, it would be assigned sub-sub-sub-cells 2-311, 2-312, 2-313, and 2-314.

Data characterizing the physical features of the cells and sub-cells were modeled using AGNPS to describe the sediment and nutrient contributions in discreet parts of the watershed. This information was used to identify cells that were responsible for disproportionate sediment and nutrient export to the lake. Four categories of AGNPS output were evaluated: (1) sediment yield; (2) cell erosion; (3) nutrient loading; and (4) hydrology.

It is important to note that Schockopee Lake is directly upstream of Cree Lake and, therefore, exerts a marked influence to diminish sediment and nutrient inputs to the lower waterbody. It was impossible to assess the water quality of Cree Lake without understanding the physical, chemical, and biological conditions in Schockopee Lake. The following discussion summarizes the AGNPS output from each of the four categories (i.e., sediment yield, cell erosion, nutrient loading, and hydrology) in the combined Cree/ Schockopee system.

Sediment Yield and Erosion

Sediment yield, as characterized by AGNPS, is the amount of sediment, in tons, that leaves a cell at its downstream edge. This figure represents not only the sediment generated inside the cell but also the sediment generated in upstream cells. It is important to note

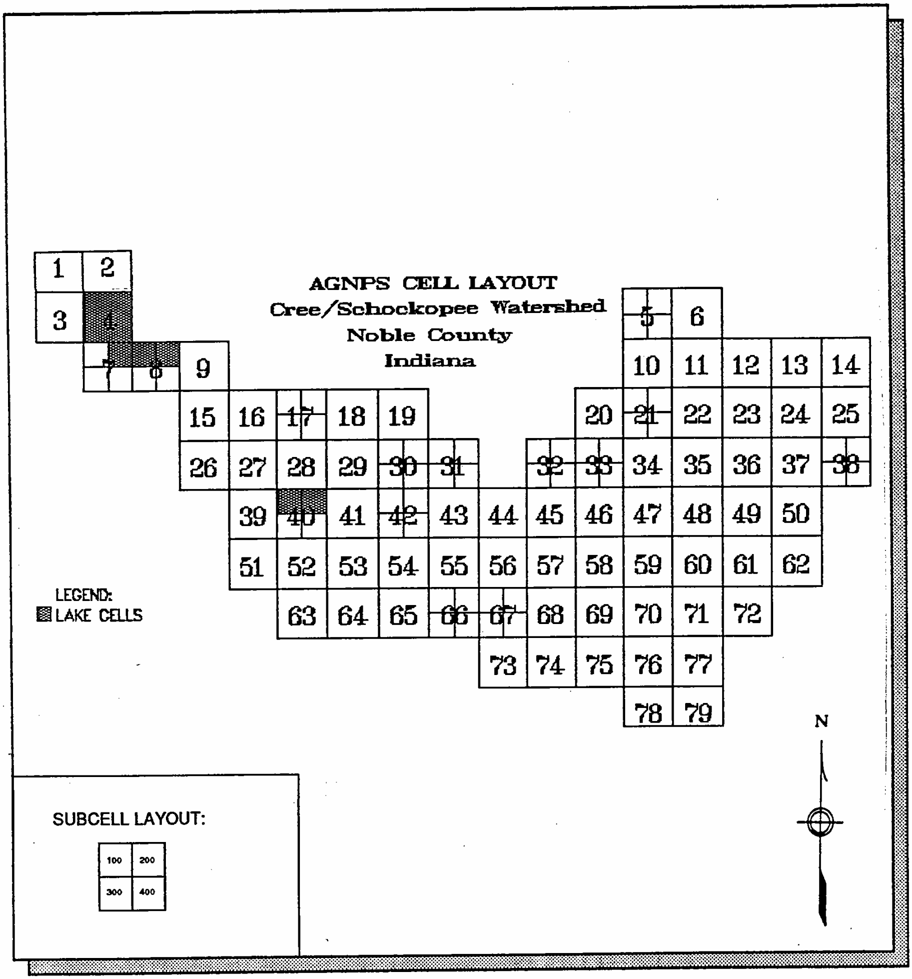

FIGURE 3-12. Layout of Cree Lake watershed cells used in the AGNPS model.

that AGNPS also accounts for sediment deposition within a cell if appropriate conditions exist. Therefore, sediment yield is calculated as the sediment generated in the cell, plus the sediment entering from cells upstream, minus the sediment deposited in the cell.

In contrast, cell erosion, as characterized by AGNPS, refers to the amount of sediment that is produced within an individual cell rather than the cumulative amount passing through the cell. It is useful in identifying areas that experience the greatest amount of internal erosion. The most important factors contributing to high erodibility within a given cell are soil erodibility (i.e.,K-factor) and land slope. Land use, water flow velocity, and the presence/absence of defined stream channels within a cell also influence erosion. Areas of intense row-crop agriculture generally produce higher erosion losses than areas consisting of forests or wetlands.

It was necessary to examine cell erosion and sediment yield separately in order to recognize source areas as opposed to conduit (i.e., "flow-through") areas. Because management options exist for both source and downstream sediment control, the distinction is often an important one. Results of the model runs are discussed below. Areas with high sediment yield and high cell erosion are displayed in Figures 3-13 and 3-14, respectively.

<u>Cree Lake Sediment Yield</u>: The total sediment yield into Cree Lake was calculated at 93 tons (84 MT). The amount of sediment yield from each cell ranged from no yield to nearly 268 tons (243 MT). The cell with the highest sediment yield, 88 tons (80 MT), to Cree Lake was cell #8-200 (i.e., cell 8, sub-cell 200). This cell represents the area adjacent to the canals which extend from the southeastern shore of Cree Lake. While the sediment generated within cell #8-200 was less than 0.01 tons (0.009 MT), the amount of sediment entering the cell from upstream sources was significant. Cell #8-200 contained the mouth of a drainage stream that transports sediment from Schockopee Lake and the area between the two lakes. Sediment yield from the other input cells to Cree Lake was inconsequential.

<u>Schockopee Lake Sediment Yield</u>: The total sediment yield into Schockopee Lake was calculated at 248 tons (225 MT). The cell with the highest sediment yield, 215 tons (195 MT), was cell #40-400. This cell represents the area directly south of the southeastern corner of Schockopee Lake and contains the mouth of a stream that drains the majority of the watershed. The total drainage area of cell #40-400 is 2498 acres (1011 ha). Therefore, sediment runoff from nearly two-thirds of the entire watershed is channeled through this cell. The dominant land use within this area was row crop agriculture with a few sizeable pockets of non-row crops. Most of the soils in this drainage area are a part of the Miami-Riddles-Brookston association, an association exhibiting moderate to high soil erodibility factors.

Several cells upstream from cell #40-400 (e.g., cells 53, 54, 55, and 56) also had sediment yields in excess of 200 tons (182 MT). Collectively, they constituted the area of highest sediment load to Schockopee Lake. While the relative sediment contributions of individual cells were not notable, the cumulative sediment drainage through this area was

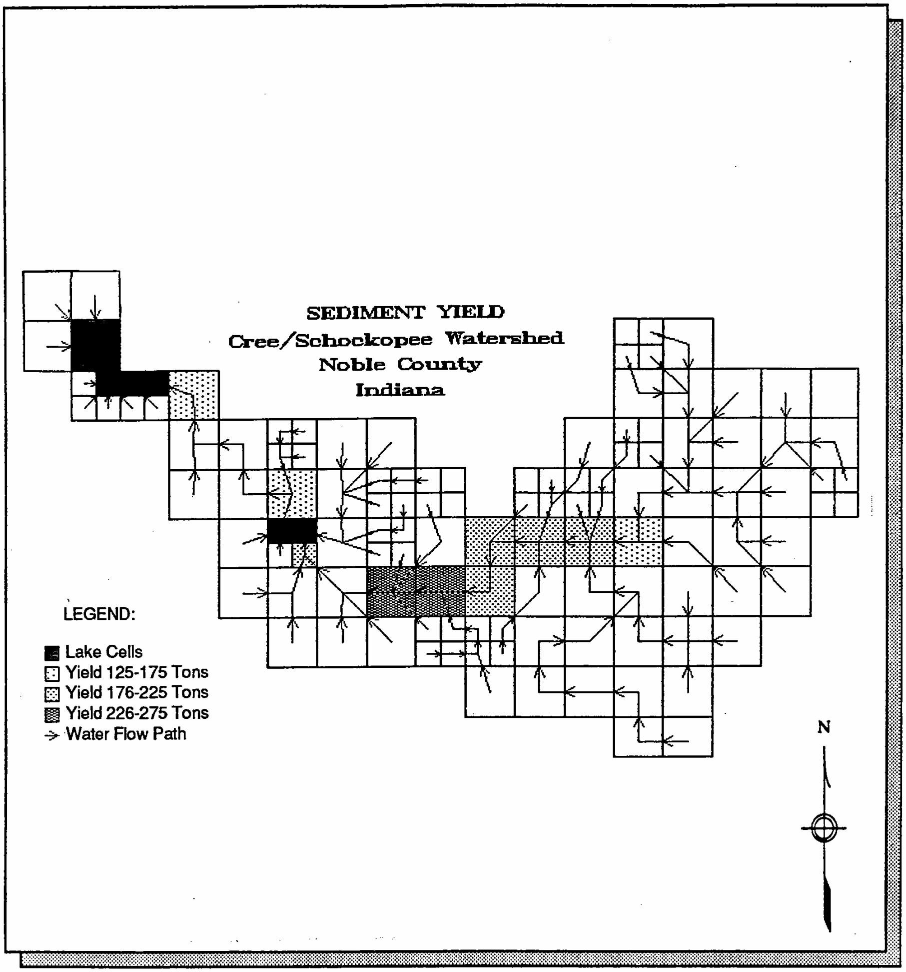

FIGURE 3-13. Modeled sediment yield for the Cree Lake watershed.

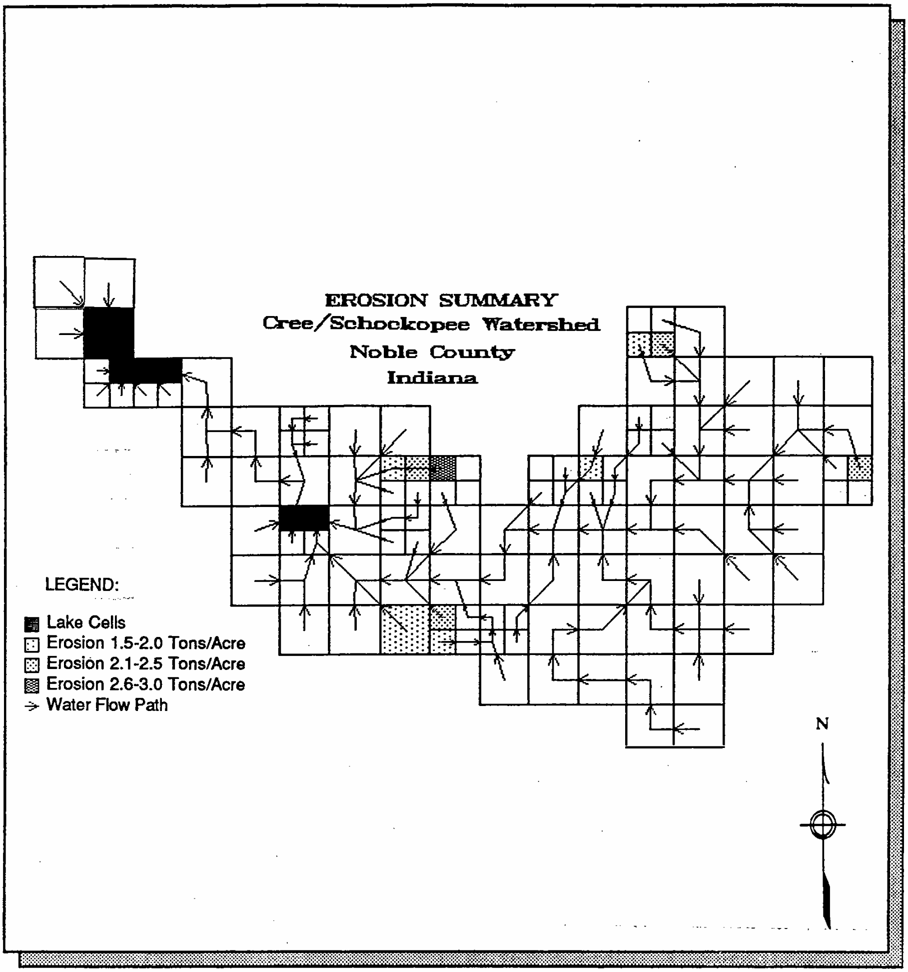

FIGURE 3-14. Modeled cell erosion for the Cree Lake wat

significant. It is important to note, however, that the location of these cells within the overall drainage scheme of Schockopee Lake, rather than their physical characteristics, explains the high sediment yields predicted by AGNPS. Specifically, the modeled sediment yield from cell #40-400 was the result of 3 factors:

1) A large sub-basin that focused runoff at cell #40-400
2) Land uses conducive to high sediment export within the sub-basin
3) Moderate to highly erodible soils within the sub-basin.

Cell erosion figures generated by the AGNPS model ranged from no sediment production to 2.76 tons/acre (6.19 MT/ha). The average value for all cells was 0.62 tons/acre (1.39 MT/ha). Cells exhibiting little or no erosion were those areas consisting of water, wetlands, or peat/clay soils. The highest rate of erosion was found in cell #31-100. This cell represents an area located north of 1000 North Road and east of 1000 East Road. The soil type in this sub-cell was classified as Miami loam and had a high "K" factor. The land use was 74% row crop agriculture and the land slope was high at 7.1%. Slope, land use, and soil erodibility all contributed to the high sediment production found in this cell. Cells #30-200, #38-200, 66-100, and #5-400 all displayed erosion production rates greater than 2.0 tons/acre (4.48 MT/ha). The land use within these 4 cells was predominantly row-crop agriculture. The soils within these areas were mostly Miami loams which have a high soil erodibility factor. The land slopes of these cells were in excess of 5% (a relatively large slope).

<u>Nutrient Loading</u>

The AGNPS model supplied estimates for nitrogen and phosphorus concentrations in runoff from the watershed. Values were produced both for sediment-bound and for soluble forms of the nutrients. Again, the model furnished predictions for the entire watershed and for individual cells. Watershed cells exporting relatively high nitrogen and phosphorus are displayed in Figures 3-15 and 3-16, respectively.

<u>Cree Lake Nitrogen</u>: Using cumulative data generated by the AGNPS model for those cells bordering Cree and Schockopee Lakes, it was possible to calculate the total nitrogen (i.e., soluble N and sediment-bound N) loading to each water body during the design storm. For Cree Lake, total nitrogen loading was 2.36 tons (2.14 MT). Approximately 87% of this amount, 2.04 tons (1.85 MT), was in the form of soluble nitrogen. Two conditions may explain this phenomenon. First, the watershed contains primarily agricultural land use patterns. Surface water runoff concentrations of total nitrogen from continuous corn production may reach as high as 131 mg/L (Burwell et al., 1975). Second, inputs of sediment to Cree Lake are low, due to the presence of Schockopee Lake upstream. Therefore, the sediment-bound component of total nitrogen loading should be correspondingly low.

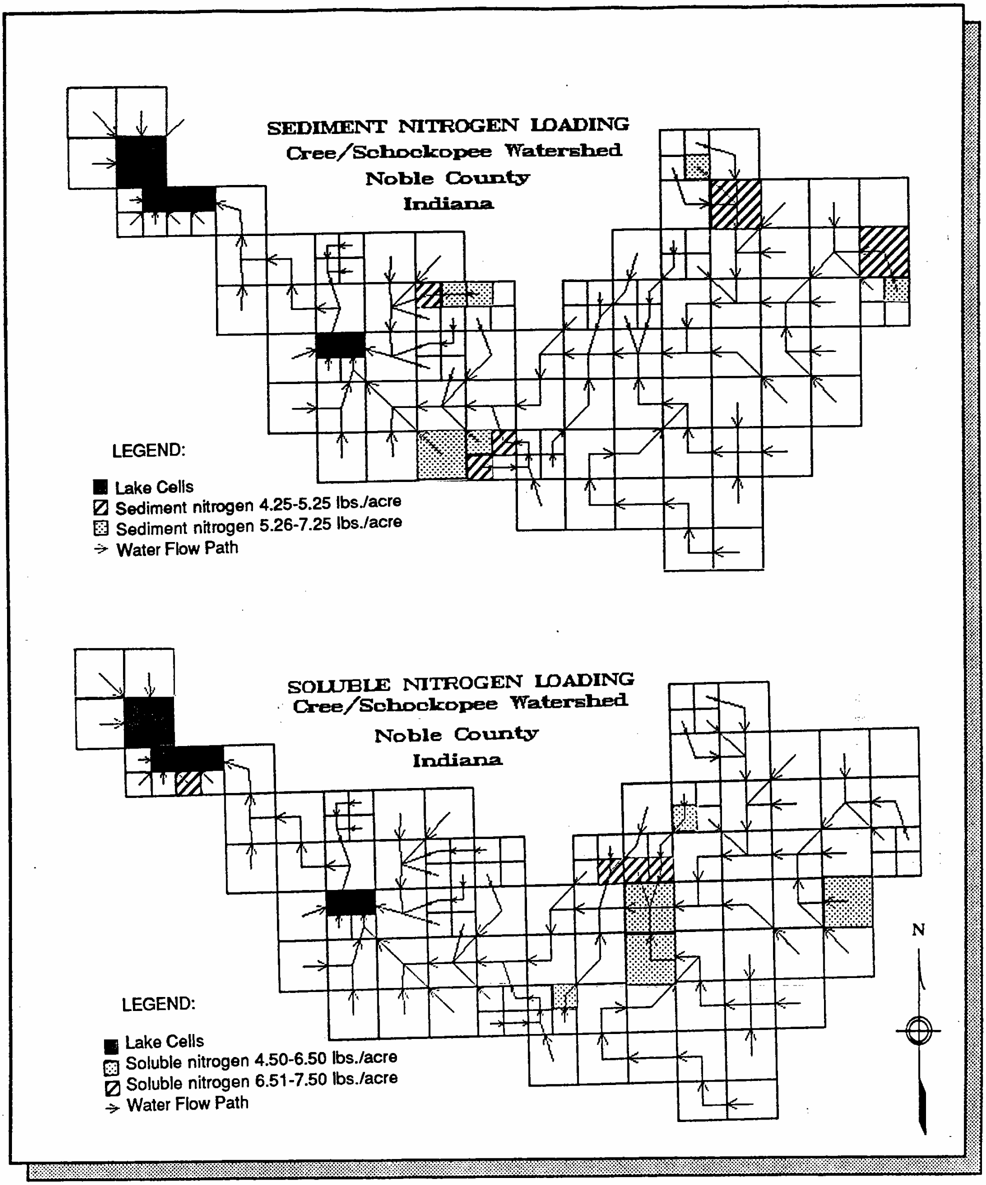

FIGURE 3-15. Modeled nitrogen loading for the Cree Lake watershed.

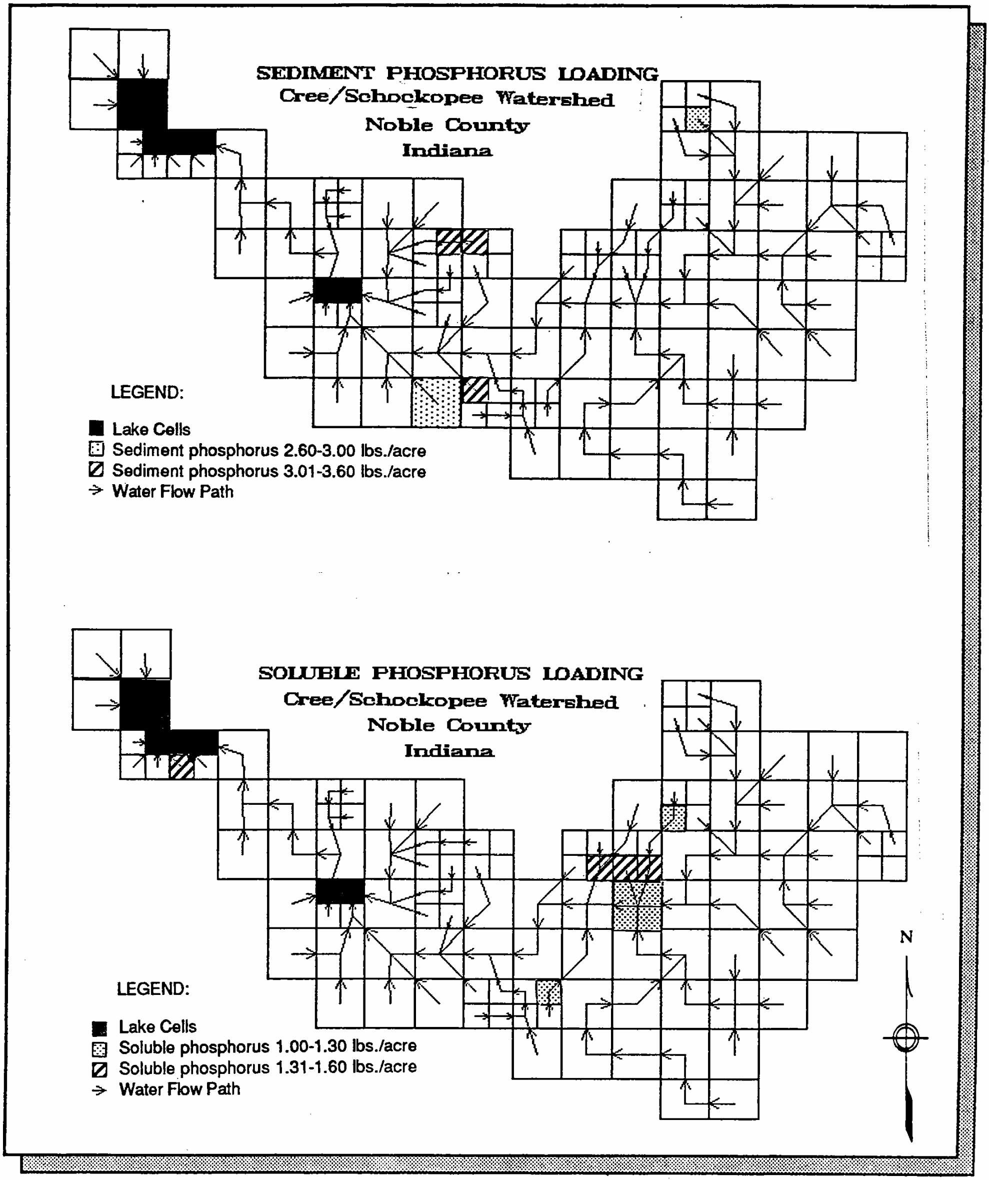

FIGURE 3-16. Modeled phosphorus loading for the Cree Lake watershed.

Schockopee Lake Nitrogen: Results from the AGNPS model run showed total nitrogen loading to Schockopee Lake to be slightly less than Cree Lake. Total nitrogen loading was 2.32 tons (2.11 MT). As with Cree Lake, the majority of the nitrogen inputs were from the soluble component (1.81 tons). However, the percent of the total nitrogen inputs from the soluble form decreased to 78%. Presumably, this decrease in percentage can be attributed to a nearly two-fold increase in the amount of sediment-bound nitrogen entering Schockopee Lake over sediment-bound nitrogen entering Cree Lake.

The impact of nutrient loading from individual cells within the Cree-Schockopee Lake watershed is shared by both lakes. Although the majority of nutrients reach Schockopee Lake first, hydraulic output from Schockopee to Cree Lake exhibits approximately the same concentration of nutrients as are found in Schockopee Lake. Therefore, discussion of the impact of individual cells will not be split between the two lakes but rather identified as problems common to both of them. The paragraphs below examine the impact of individual cells on nitrogen loading.

Soluble nitrogen generated within individual cells ranged from 0.01 pounds/acre (0.01 kg/ha) to 7.36 pounds/acre (8.24 kg/ha). The highest value was observed in cell #33-300, a cell representing an agricultural/residential area located in the north central portion of the watershed between 1000 and 1100 East Roads and just south of 1000 North Road. Sediment-bound nitrogen generated in individual cells ranged from 0.00 pounds/acre (0.00 kg/ha) to 6.29 pounds/acre (7.05 kg/ha). The highest value was observed in cell #30-200, a cell representing an area completely under row crop agriculture, located between 900 and 1000 East Roads and just north of 1000 North Road. Most of this load can be explained by the high erosion rate within the cell (2.36 tons/acre).

Cree Lake Phosphorus: Total phosphorus loading to Cree Lake was 0.54 tons (0.49 MT). Of this amount, 0.39 tons (72.4%) was in the soluble form. As was the case with total nitrogen, runoff from agricultural land and low sediment inputs to Cree Lake explain this phenomenon.

Schockopee Lake Phosphorus: The total phosphorus loading to Schockopee Lake, 0.61 tons (0.55 MT), was slightly higher than that received by Cree Lake. Approximately 58% of this amount, 0.35 tons (0.32 MT), was in the form of soluble phosphorus while 42%, 0.26 tons (0.24 MT), was sediment bound. As with nitrogen, the amount of sediment-bound phosphorus entering Schockopee Lake was nearly twice that which entered Cree Lake. Clearly, the high sediment loading to Schockopee Lake is the single largest factor in explaining the quantity of sediment-bound phosphorus predicted by the model. The discussion below examines the impact of individual cells on phosphorus loading to the Cree-Schockopee system.

Soluble phosphorus values generated by the AGNPS model for individual cells ranged from 0.00 pounds/acre (0.0 kg/ha) to 1.57 pounds/acre (1.71 kg/ha). The upper end of the range was found in cell #33-300. This cell represents an area located along 1000

North Road between 1000 and 1100 East Roads. Row crops accounted for over 80% of the land use while low-density residential land use made up the remaining area.

Sediment-bound phosphorus exhibited a range of 0.0 pounds/acre (0.0 kg/ha) to 3.56 pounds/acre (3.99 kg/ha). Cell #31-100 generated the highest value. This area also exhibited the highest level of cell erosion (2.76 tons/acre). Cell #30-200 and cell #66-100 had sediment bound phosphorus production rates in excess of 3.0 pounds/acre. Cell #30-200 represents an area located adjacent to the west side of cell #31-100.

Hydrology

The AGNPS model was also used to examine hydrologic inputs to both Cree and Schockopee Lakes. Results for both lakes are presented below. Watershed cells producing high runoff are displayed in Figure 3-17.

Cree Lake: Hydrologic input to Cree Lake was estimated to be 9.80×10^6 cubic feet (2.78×10^5 m^3). The area that contributed the greatest volume per acre, 5627 cubic feet (159 m^3), was cell #33-300. Cell #33-300, located south of 1000 North Road and between 1000 and 1100 East Roads, was found to be 80% row crop and 20% low density residential. Its high hydraulic contribution was believed to be the result of runoff from agricultural lands and impervious areas associated with residential properties.

Schockopee Lake: Hydrologic inputs to Schockopee Lake were estimated at 8.17×10^6 cubic feet (2.31×10^5 m^3). Cell #33-300, which is part of Cree Lake's sub-watershed, remained the highest per-acre source of runoff.

3.2.6 Septic Tank Phosphorus Inputs

The input of phosphorus from septic fields located in the vicinity of a lake may be significant. Because these systems are subject to limited capacity and frequent high water tables, elevated concentrations of phosphorus may be transported to the waterway via groundwater. Factors that influence nutrient export from septic systems to a nearby surface water body include: (1) capacity of leach field soils to attenuate nutrients; (2) distance between leach fields and the lake; (3) number of people using septic systems; and (4) per-capita inputs to septic systems.

The attenuation capacity of the soil is the first important factor influencing the nutrient load from septic systems. This value can be represented by a "nutrient retention coefficient" that ranges from 0.00 (no retention) to 1.00 (complete retention) and indicates percent of the total septic input immobilized by a septic tank/leach field combination. Retention coefficients are influenced by soil drainage, permeability, slope, soil type, and soil pH. System age, maintenance levels, rainfall frequencies, and plant uptake also affect attenuation.

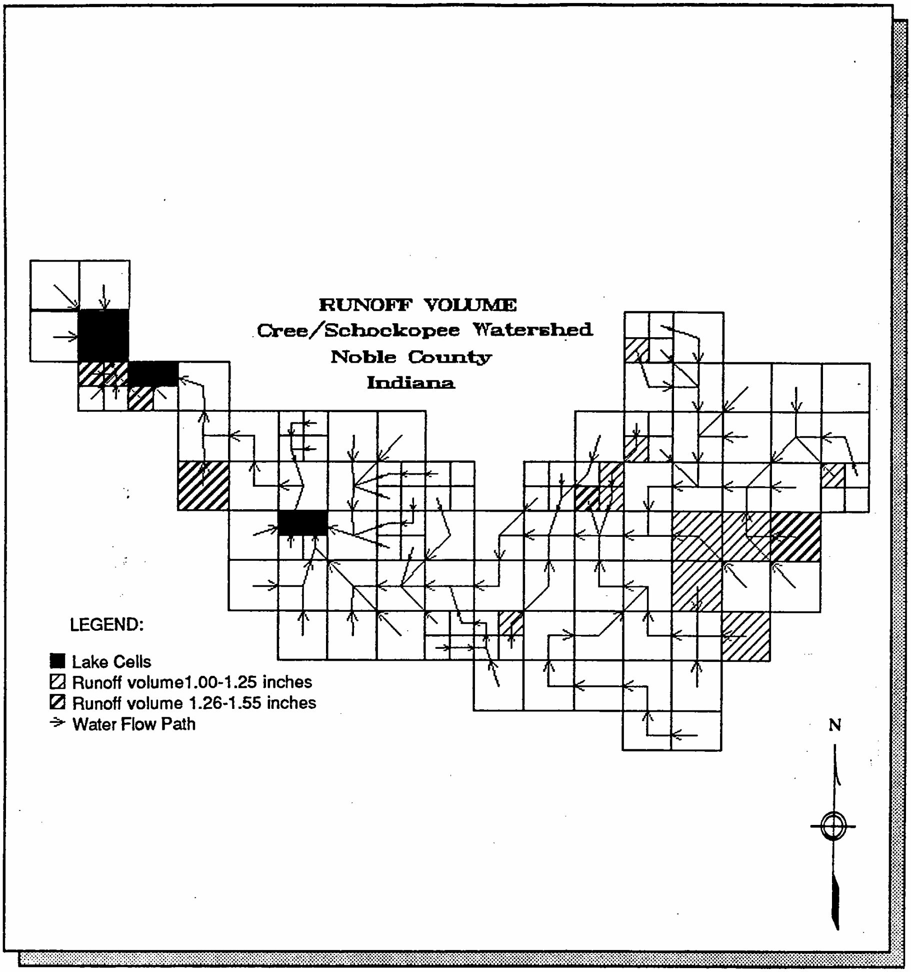

FIGURE 3-17. Modeled cell runoff for the Cree Lake watershed.

Homes located along the perimeter of Cree Lake (excluding the canal system) are situated within a band of Edwards muck, a soil characterized by poor drainage, high permeability, and minimal depth to the water table (0-1 foot). The Soil Survey of Noble County lists this soil as "severe" (the worst categorization) for construction of septic tanks. Muck soils are poor choices for septic tanks because soil water saturation results in anoxic conditions that limit nutrient uptake by bacteria. In addition, the high water table associated with these soils tends to "flush" waste materials directly into adjacent bodies of water before they can be bound to soil particles.

Homes along the canals on the southeastern side of Cree Lake are situated on two different soil types. Approximately one-half of the area is covered by Edwards muck while the other half consists of 2 pockets of Fox sandy loam. Fox sandy loam has few restrictions for the construction of septic systems. The substratum at a depth of 3-5 feet (0.9 to 1.5 m) is typically sand and gravelly sand that exhibits rapid permeability and poor nutrient attenuation.

Homes associated with Schockopee Lake are situated primarily south of the water body in a large band of Martinsville fine sandy loam. Unlike the Cree Lake sites, this development is not directly adjacent to the water body. This soil type has properties similar to Fox sandy loam. Soil profiles of the residential areas of the Cree and Schockopee Lake watershed are presented in Figure 3-18.

There is a direct relationship between the age of a septic system and its capacity to retain phosphorus. As a system becomes older, the nutrient-binding sites of drain field soils become saturated and are less able to attenuate nitrogen and phosphorus. Often, however, records reflecting the age of septic systems are not available and surrogate figures must be used. For the purposes of this study, septic system ages were assumed to be the same as the ages of the residences they served. Officials at the Noble County Board of Health estimated that the average age of the homes located along the perimeter of Cree Lake were 30 to 40 years old. An average age of 35 years was used in the evaluations. The homes adjacent to the Cree Lake canal system and to the south of Schockopee Lake were estimated to be 20 years old.

Hill and Frink (1974) investigated the longevity of septic systems in various soil types and defined the "half-life" of a septic system as the average number of years required for the cumulative failure rate of entire population of septic systems to reach 50%. For glacially-derived soils the half-life was determined to be 27 years (discussions with the Noble County Board of Health suggested that a more realistic estimate of the half-life of systems in the muck soils along Cree Lake would be approximately 7.5 years). Assuming a linear relationship between the age of a system and the amount of phosphorus retained, new systems located in glacially-derived soils would attenuate 100% of the phosphorus entering them, 27 year old systems would attenuate 50% of the phosphorus, and 54 year old systems would attenuate 0% of the phosphorus. Similarly, new systems in muck soils would retain 100%, 7.5 year old systems would retain 50%, and 15 year old systems would retain 0%.

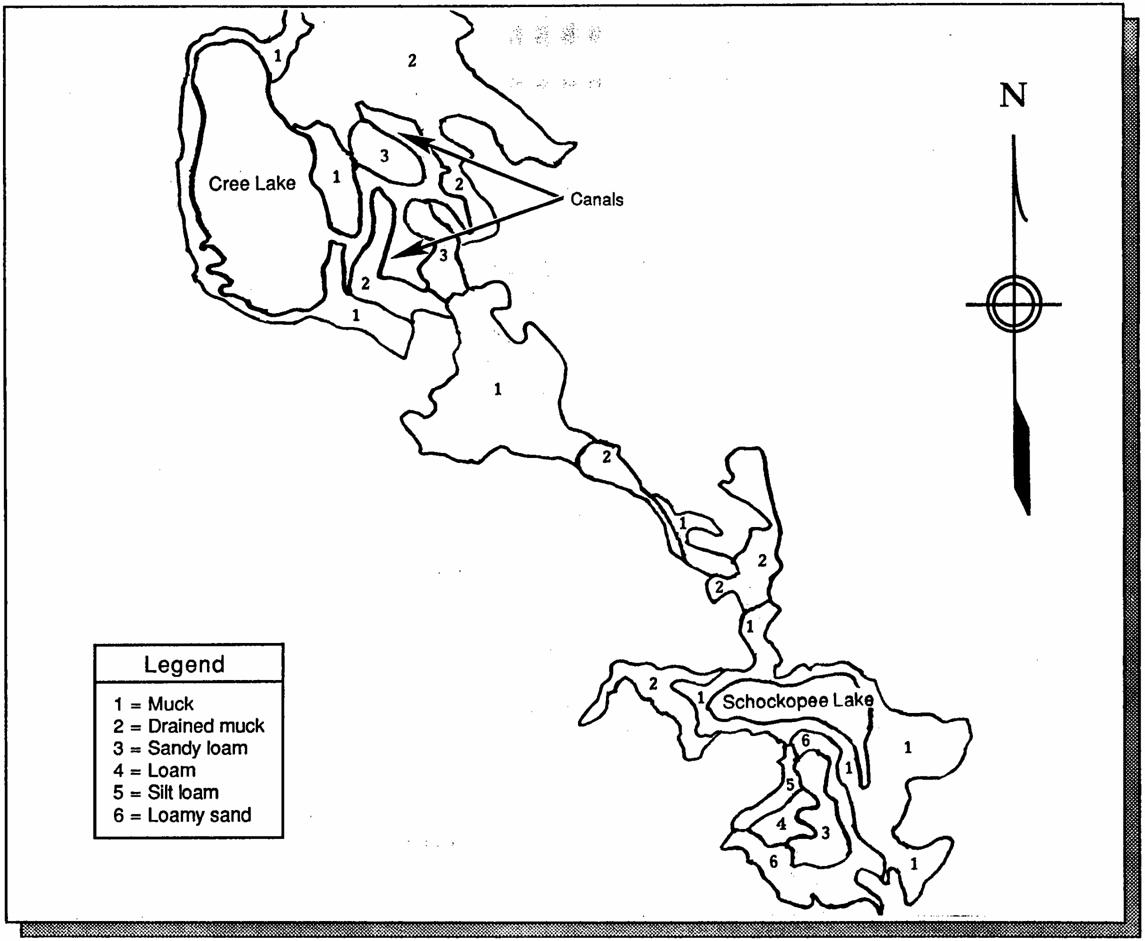

FIGURE 3-18. Soil profile of the residential areas of the Cree and Schockopee Lake watershed.

Half-life designations and retention figures for Cree and Schockopee Lake sites are presented in Table 3-21.

Table 3-21. Half-life designations and retention figures for Cree and Schockopee Lake residences.

Lake	Soil Type	System Age (years)	Half-Life (years)	Drain Field P Retention (%)
Cree	Edwards muck	35.0	7.5	0.00
Cree Canals	Edwards muck	20.0	7.5	0.00
Cree Canals	Fox sandy loam	20.0	27.0	63.00
Schockopee	Martinsville fine sandy loam	20.0	27.0	63.00

It should be noted that approximately 42.5% of the phosphorus entering a septic system is removed in the septic tank before the wastewater reaches the drain field (Reckhow et al., 1980; Sawheny and Hill, 1975; Bache and Williams, 1971). Because phosphorus removal processes in septic tanks involve physical settling, the retention efficiency is assumed to remain constant over time, given normal system care. Understanding that 42.5% of the phosphorus entering septic systems is removed in the septic tank, it is reasonable to conclude that 57.5% enters the drain field. Therefore, the phosphorus retention figures listed in Table 3-21 are applied to only 57.5% of the total phosphorus produced in households.

Distance between septic systems and the water body is the second important factor in determining septic impacts to a lake. Generally, as the distance between a water body and a septic system increases, the amount of nutrients reaching the water body from the system decreases. For Cree Lake only those systems situated directly adjacent to the lake and along the canal system were evaluated for septic loading. For Schockopee Lake, houses adjacent to the lake and situated immediately to the south were included.

The number of people using septic systems in the watershed is the third important factor in determining septic loading to a lake and can be represented by a "capita-year" figure. This value combines estimates of permanent and seasonal populations, the number of septic systems used, and the fraction of the year the systems are used. A capita year is essentially the average number of residents per dwelling unit, multiplied by the number of dwelling units, multiplied by the fraction of a year the residents are home.

Capita years for the Cree/Schockopee watershed were calculated using diverse sources of information. An interview with the Noble County Auditor's Office revealed that the average household in Wayne Township contained 2.69 full-time residents. Because reliable data for seasonal occupancy of the dwellings around the lakes were unavailable, all occupants were believed to be full-time residents). The capita year figures for the lakes in this study are presented in Table 3-22.

Table 3-22. Capita year data for Cree and Schockopee Lakes.

Lake	Soil Type	Number of Dwellings	Number of Residents[a]	Time at Home[b]	Capita Years
Cree	Edwards muck	119	320	90%	288
Cree Canals	Edwards muck	21	56	90%	50
Cree Canals	Fox sandy loam	29	78	90%	70
Schockopee	Martinsville fine sandy loam	34	91	90%	82

[a]Number of residents = number of dwellings * number of residents per dwelling (i.e., 2.69).

[b]Time at home = fraction of year residents are at not on vacation, extended trips, etc.

The fourth important factor influencing septic loading is per-capita nutrient input to septic systems. This value is simply the nutrient mass, per capita, per year that enters a septic system and is the aggregate of inputs from toilets, showers, basins, laundry rinse, and other household waste water. It is often represented by an export coefficient in kg/capita year. A review of the literature revealed that the average person produces 44.6 gallons (169 l) of waste water per day (Chan, 1978; Brandes, 1977; Otis et al., 1974; Bouma et al., 1972; Feth, 1966; Preul, 1964). The average total phosphorus concentration was found to be 20 mg/l. Therefore, the average annual total phosphorus production was determined to be 2.71 pounds per capita (1.23 kg/capita).

Total phosphorus production by households adjacent to Cree and Schockopee Lakes is presented in Table 3-23 along with values for septic tank retention, and leach field retention. Total phosphorus loadings to each water body are listed in Table 3-24. Under current conditions, Cree Lake receives approximately 567.1 pounds (257.4 kg) of total phosphorus from septic systems annually. Twenty-one percent of this amount, 118.3 pounds (53.7 kg), is input to the canals, while 83%, 448.8 pounds (203.7 kg), enters the main body of the lake. In comparison, Schockopee Lake receives approximately 47.3 pounds (24.2 kg) each year. This relatively small figure reflects the better soils and larger distances between septic systems and the lake at Schockopee.

Table 3-23. **Total phosphorus production/retention by household for Cree and Schockopee Lakes.**

Lake	Soil Type	Household P Production (lbs)	(kg)	Septic Tank Retention (lbs)	(kg)	Leach Field Retention (lbs)	(kg)
Cree	Edwards muck	780.5	354.2	331.7	150.5	0.0	0.0
Cree Canals	Edwards muck	135.5	61.5	57.6	26.1	0.0	0.0
Cree Canals	Fox sandy loam	189.7	86.1	80.6	36.6	68.7	31.2
Schockopee	Martinsville fine sandy loam	222.2	100.9	94.4	40.1	80.5	36.6

Table 3-24. **Total phosphorus from septic systems to Cree and Schockopee Lakes.**

Lake	Soil Type	Loading (lbs) (kg)	Lake Phosphorus
Cree	Edwards muck	448.8	203.7
Cree Canals	Edwards muck	77.9	35.4
Cree Canals	Fox sandy loam	40.4	18.3
Cree Total	All soils	567.1	257.4
Schockopee	Martinsville fine sandy loam	47.3	24.2

3.3 SOURCES OF SEDIMENTS AND NUTRIENTS

Based on the results of the watershed analysis, storm sampling, and visual observations, major sources of sediments and nutrients were identified for both Cree and Schockopee Lakes. Although the major issue prompting the Cree Lake Association to request this feasibility study was a significant loss of depth in the Cree Lake canal system, it appears that the input of sediment may play only a partial role in the overall shoaling problem. Based on the richly organic nature of the canal sediments and on the estimates of elevated septic loading, it is believed that much of the depth loss is the result of increased algal and macrophyte production in the confined canal areas. Elevated nutrient concentrations contribute to accelerated production of plant material (i.e., biomass) during the growing season, which in turn leads to increased senescence and decay during the winter. Sloughed macrophyte materials and dead algal cells settle to the bottom where they tend to accumulate, thereby reducing water depth. Therefore, it is important to identify sources of both sediment and nutrient inputs. The following sections outline principal sources of each type of pollutant in the watershed.

3.3.1 Sediments

Sediment inputs to both lakes are generated by upland sources in the watershed. Although no specific problem areas were identified, it is reasonable to conclude that the overwhelming majority of sediments originate from activities associated with row-crop agriculture. Generally, the areas with the highest erosion/sedimentation rates are those that combine intensive-till farming, hilly slopes, and erodible soil types. These combinations occur within the Cree/Schockopee watershed at AGNPS cells #5, #30, #31, #38, #65, and #66. Sediments can also be produced in stream channels if stream flow velocity is high enough to cause dislodging of bed or bank particles. The largest sediment loads can be expected in streams flowing through AGNPS cells #9, #28, #40-300, #44, #45, #46, #47, #54, #55, and #56.

Whether originating on agricultural fields or in stream channels, sediment yields vary greatly from storm to storm. Within a given area, the largest annual sediment loads in runoff are often 20 times greater than the minimum sediment loads (NCAES, 1982). Even within the same stream, concentrations of suspended solids can vary by a factor of 10 for a distinct rate of water discharge. Therefore, even though areas have been identified in this study as potential sediment trouble spots, others that were not captured by this investigation may exist.

Almost all of the sediment reaching Cree and Schockopee Lakes is transported by a single tributary system. This system empties first into Schockopee Lake, which acts as a *de-facto* detention basin, slowing flow velocity and allowing sediments to settle. The partially "treated" water then continues to the canal system at Cree Lake via the stream created by the Schockopee overflow. The evidence of this "treatment" effect was observed in the results of storm monitoring. Water entering Schockopee Lake from its tributary during the sampled event contained 40.2 mg/l of total suspended solids, whereas water entering Cree Lake from its tributary contained only 7.4 mg/l.

3.3.2 Nutrients

Generally, the most important plant nutrients impacting the trophic status of lakes are nitrogen and phosphorus. Based on relatively high N:P ratios in Cree and Schockopee Lakes (i.e., 75:1 and 53:1, respectively), it was concluded that phosphorus was the limiting nutrient in both water bodies. The following sections present major sources of the plant nutrient in each lake.

Cree Lake

This study identified four major sources of phosphorus to Cree Lake. They include:

- Leachate from septic systems along the lake shores
- Recycling from the organically-rich canal bottoms
- Runoff from agricultural practices in the watershed
- Deposition from the atmosphere

<u>Septic Leachate</u>: The estimated annual phosphorus loading from septic systems, 567.1 pounds (257.4 kg), indicates that septic system inputs are a significant source of nutrients to the lake. Moreover, inputs from septic system leakage tend to be evenly distributed over time and are released in a soluble form that is immediately available for biological uptake. This is in contrast to nutrient inputs from the watershed which are principally associated with storms, and are in particulate and soluble forms which may be only fractionally available for immediate uptake by algae and macrophytes.

Evidence of the significance of septic inputs may be found in the uniformly high levels of algal and macrophyte productivity observed throughout the canal system, regardless of proximity to the tributary carrying the majority of watershed drainage. If this tributary was the single major source of nutrients, the density of algal and macrophyte growth would be expected to be significantly lower in the far reaches of the canal system compared to the embayment into which the tributary discharges.

The problem is exacerbated in the canals where water circulation and flushing are low. Approximately 21% of the phosphorus reaching Cree Lake from septic systems enters the water body as leachate from the homes along the canals. The reduced circulation, even distribution of inputs, and the readily-available (i.e., soluble) form of phosphorus normally associated with septic loading, all combine to produce conditions favorable to enhanced plant growth.

<u>Sediment Recycling</u>: The accumulation of highly organic sediments in the canal system of Cree Lake represents another probable source of nutrient loading to the system. Although

it is not possible to quantitatively estimate the magnitude of this input, it is undoubtably significant given the depth and extent of coverage.

Runoff: Nutrients reaching Cree Lake in runoff from the predominantly agricultural watershed are also important to the trophic status of the water body. Using AGNPS, it was estimated that 1,080 pounds (489.9 kg) entered Cree Lake during the design storm (i.e., 2 year, 24 hour event). Of this amount, 72% was estimated to be in the soluble form and thus, readily available to aquatic plants. The majority of this input was transported to the lake via the small stream that discharges into the canal system. Storm event sampling along this tributary, however, revealed that only about 27% of the phosphorus reaching the lake in runoff was in the soluble form. This difference was attributed to the following factors:

- Modeling was performed for the 2 year, 24 hour event; storm sampling was conducted during an event of much greater frequency.
- Modeling incorporated inputs from the entire storm; sampling revealed inputs at a discreet moment in time (i.e., actual input levels and solubility fractions vary considerably over the duration of a runoff event).

Even with these apparent discrepancies, however, nutrients reaching the lake in runoff must be considered significant.

The confined nature of the canal system in Cree Lake intensifies the impact of runoff loading to the water body. As water from the stream enters the water body, its velocity is reduced and the sediment load begins to settle. Most sediment-bound phosphorus entering in runoff can be expected to remain in the canal system because of this physical phenomenon. When low circulation conditions resume following a rainfall event, the canals may become anoxic, causing the new sediments to release their phosphorus load into the water where it becomes available to plants.

Soluble phosphorus entering the canals in runoff can be expected to be distributed in the same pattern as the incoming water itself. A fraction of this input will be attenuated by plants, but, in the short-term, most will circulate with the water. Under normal flow and during mild storm events, runoff volume will not be high and the dissolved phosphorus will not be rapidly transported out of the canals into the main body of the lake. Because soluble phosphorus does not flush out of the canal system and because this form of the nutrient is immediately available for plant uptake, eutrophic conditions develop readily in this part of Cree Lake.

Atmospheric Loading: Annual atmospheric phosphorus deposition to Cree Lake and the canal system was calculated to be 33.0 pounds (15.0 kg). This addition was not considered very significant because it was uniformly spread across the entire surface of the lake, including the canal system, and because it was at least an order of magnitude less than other input sources. Moreover, there is no practical technology readily available to the Cree Lake Association for controlling atmospheric deposition.

Schockopee Lake

As in Cree Lake, the major sources of phosphorus to Schockopee Lake include septic systems, sediment recycling, runoff, and atmospheric deposition. In contrast to Cree Lake, however, contributions from runoff and sediment recycling were believed to be much more significant than those from septic systems and atmospheric deposition. Each of these sources is discussed below. A comparison of the phosphorus loadings to both lakes is summarized in Table 3-25.

Table 3-25. Sources of phosphorus loading to Cree and Schockopee Lakes.

Phosphorus Sources	Cree Lake	Schockopee Lake
Septic Leachate	567.1 lbs/year	222.2 lbs/year
Sediment Recycling	***	***
Runoff	1197.0 lbs/storm	1220.0 lbs/storm
Atmospheric Loading	33.0 lbs/year	11.9 lbs/year

*** denotes that no estimate was quantified.

Septic Leachate: Total phosphorus contributions to Schockopee Lake from septic systems were calculated to be 222.2 pounds (100.9 kg) annually. Although this figure is not as high as its counterpart in Cree Lake, it is still considered significant because the nutrient enters the water body in soluble form and is immediately available to aquatic plants. It is not as important to Schockopee because there are no confining canals that limit circulation and the input is diluted by the entire volume of the lake.

Sediment Recycling: Although it was not quantified in this study, nutrient recycling from bottom materials may be considered an important source in Schockopee Lake due to the high input of sediment from the agricultural watershed. The water body receives most of the runoff from the catchment basin of both lakes and acts as a settling pond, removing a major portion of the sediment load from the water before it continues toward Cree Lake. When bottom conditions become anoxic, it is likely that much of the bound phosphorus is released from the sediments.

Runoff: Runoff is probably the most significant contributor of phosphorus to Schockopee Lake. Using AGNPS, it was estimated that 1,220 pounds (553.4 kg) entered the water body during the design storm (i.e., 2 year, 24 hour event). Of this amount, 58% was in the soluble form and thus, readily available to aquatic plants. Conversely, 42% was estimated to be sediment bound. Storm event sampling along the main tributary, however, revealed that only about 31% of the phosphorus reaching the lake in runoff was in the soluble form. Again, these discrepancies were attributed to differences between the design storm and the sampled storm and to the temporally variable nature of conditions in the stream being monitored.

Atmospheric Loading: Annual atmospheric phosphorus deposition to Schockopee Lake was calculated to be 11.9 pounds (5.4 kg). Again, this addition was not considered very significant because it was uniformly spread across the entire surface of the water body and because it was at least an order of magnitude less than other input sources. Moreover, there is no practical technology readily available to the Cree Lake Association for controlling atmospheric deposition.

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SECTION 4. SEDIMENT AND NUTRIENT MITIGATION TECHNOLOGIES

An overview of nutrient and sediment mitigation technologies is presented in this section of the report. Discussion focuses on three distinct areas: upland watershed controls; septic system remedies; and in-lake sediment removal. Potential sources of additional information and funding for these operations are listed at the end of this section.

4.1 UPLAND WATERSHED CONTROLS

Control of sediment and nutrient inputs in upland areas generally involves installation of various best management practices (BMPs) at a number of locations in the watershed. Because no single area was identified as contributing excessive amounts of these pollutants, and because the sources are located on private agricultural lands throughout the watershed, it is suggested that the Cree Lake Association encourage and coordinate placement of BMPs through the local office of the Noble County Soil and Water Conservation District (SWCD), U.S. Soil Conservation Service (SCS), and the U.S. Agricultural Stabilization and Conservation Service (ASCS), all located in Albion, Indiana. A general overview of the available control technologies is presented below.

4.1.1 Sediment Control Methods

The control of erosion and sedimentation requires an understanding of the underlying causative mechanisms. Water erosion, as evident in the Cree/Schockopee watershed, is the result of detachment of soil particles either from the impact of raindrops or from the shear forces of water as it flows across the surface of the ground. The principal mechanism at work at the field level, however, is raindrop impact (NCAES, 1982). In addition to causing particle detachment, splashing raindrops tend to break down soil aggregates into smaller pieces which are more readily carried in runoff. Furthermore, the force of the falling raindrops can lift particles into overland flow that would not otherwise be transported. These particles tend to travel a short distance downslope before settling back to the soil surface. Repeated impacts of raindrops can cause significant particle movement.

Sedimentation occurs when the carrying capacity of overland flow is exceeded and particles begin to settle, usually as the result of reductions in flow velocity. Larger-grained sediments and aggregates are deposited first, with finer-grained sediments falling out along a continuum as velocity decreases. Pools or bends in stream channels where the velocity of flowing water is diminished often serve as sinks for eroded upland soil. Similarly, lakes can experience extensive loss of depth at the mouths of tributaries where flowing water enters standing water.

It has been found that deposition of sediment can actually increase the energy potential of flowing water, causing more detachment and transport in downstream areas. McDowell and Grissinger (1976) discovered that upland control measures that decrease soil loss more than runoff actually created channel instability lower in the watershed. Because pools and bends in stream channels often serve as sinks for sediments, if upland soil erosion is reduced without corresponding reductions in runoff, these areas may become scoured, producing high sediment yields for several years while the stream system comes back to an equilibrium. For this reason, sediment control measures that decrease runoff volume are generally more effective in improving the water quality of receiving bodies (i.e., lakes).

Although it is true that controlling erosion will control sediment, there are some key differences from a management perspective that influence the choice of an appropriate mitigative approach. The most important of these differences is that erosion can only be controlled at its source while sedimentation can be managed potentially at any point between the source and the receiving body. Logically, therefore, sediment control strategies are usually separated into two general categories: (1) those that reduce the amount of field erosion, and (2) those that reduce the sediment delivery to receiving systems. Selection of appropriate combinations of control measures depends on the objectives held by those seeking mitigation. Controlling erosion has impacts on agricultural productivity (sometimes positive and sometimes negative) and on water quality. Controlling sediment, however, generally affects only water quality.

Numerous erosion/sediment control strategies have been initiated under the direction of the SCS. The most common of these techniques are briefly described, below.

<u>Conservation Tillage Systems</u>: Techniques covered under this title include no-till agriculture, minimum-till agriculture, sod-crop planting, chisel plowing, and slot planting. These practices generally reduce the volume of surface runoff and prevent erosion by reducing the amount of soil left without protective vegetative cover. Soil loss reductions of up to 99% have been observed for conservation tillage systems (NCAES, 1982). A major benefit to farmers in the Cree/Schockopee area is that conservation tillage increases the infiltration capacity of the soil, thereby counter-balancing the large volumes of water potentially lost through evapotranspiration. Because these strategies often require more precise timing of crop-related activities (e.g., soil turning, agrochemical application) than traditional practices, farmers using conservation systems must be prepared to allocate more resources to planning and management. With proper attention to details, however, initial increases in production costs (i.e., fertilizers, pesticides) can be offset by benefits associated with long-term maintenance of soil productivity.

<u>Contour Farming</u>: Techniques covered under this title include plowing, planting, and cultivation along elevation contours. Rows are arranged to run perpendicular to the slope so that the velocity of flowing water does not become too great. Ridges and furrows can be added to allow small-scale ponding of surface water, resulting in more infiltration and less runoff. This method is best used on slopes of less than 8% and in areas with minimal depressions and gullies. These conditions are met in the Cree/Schockopee watershed.

<u>Cover Crops</u>: Techniques under this title include planting a crop of close-growing grasses, legumes, or small grains during the non-growing season to protect the soil on fields where

cash crops are tended during the growing season. The cover crop not only provides vegetative protection to the soil, but also can be used to build field fertility and cash crop production when using nitrogen-fixing, leguminous cover. In areas where spring conditions are often wet, cover crops can facilitate the soil drying rate through increased evapotranspiration, thereby enabling more timely planting of the cash crop. In northern regions, however, evapotranspiration can slow warming of the soil and delay planting of the cash crop. These two effects must be balanced when considering this technique.

Diversions: Techniques under this title are designed to create channels across the slope with a supporting ridge along the downhill side. The purpose is to reduce the soil transport capacity of runoff by reducing the slope length (i.e., reducing runoff velocity). Diversions are also used to protect sensitive downslope areas from increased erosion or sediment deposition that might result if flows were not diverted. This measure yields the best results if used in conjunction with some other sediment control mechanism.

Grassed Waterways: Techniques under this title include construction of vegetated areas in natural depressions or along field borders where runoff tends to concentrate. These structures act to prevent rill and gully formation. They also reduce flow velocity and physically filter sediment from runoff, causing in-field deposition of sediments. This practice yields the best results if used in conjunction with some other sediment control strategy.

Grass/Legume Rotation: Techniques under this title involve planting a sod crop during one year of a three or four year rotation. This strategy has been shown to reduce soil loss by 80% relative to continuous corn (NCAES, 1982). Rotating crops improves the soil structure, organic matter content, and infiltration capacity when compared to continuous row cropping. In many instances, cash crop yields during "in" years are greater on fields that have been under previous grass/legume rotation.

Sediment Basins: Techniques under this title include construction of basins or depressions to retain sediments that have already been detached and transported from the field, before they reach a sensitive stream or lake. Sediment basins are extremely effective in trapping small-sized particles due to dramatic reductions in flow velocity associated with such basins. Because little or no sediment is produced from small rainfall events, these structures are best used as a back-up to on-site controls for severe storms. Schockopee Lake is currently acting as a *de-facto* sediment basin for Cree Lake.

Stream Channel Stabilization: Techniques under this title include the installation of slotted board fencing, concrete jacks, and/or stone riprap along stream channels to reduce bank and bed erosion. These measures are aimed at controlling impacts from upland strategies that decrease soil loss without reducing runoff volume. A thorough knowledge of the original conditions in the stream channel is necessary, however, to determine what changes will result from upstream activities.

Terraces: Techniques under this title are designed to reduce slope length and steepness, thereby diminishing sediment transport capacity. Terraces may be placed into one of two categories: (1) those that are graded to divert water into a grassed waterway or similar structure, and (2) those that are level to hold water on the field and increase infiltration. Although these structures can be quite effective, outlays for construction may not allow this alternative to be cost-effective.

Filter Strips: Techniques under this title involve planting strips of vegetative cover along field borders and stream corridors to intercept sediment before it can enter a water body. Filter strips are probably most effective when used in conjunction with erosion prevention measures since their sediment retention capacity can be easily exceeded during intense runoff events.

Generalized cost estimates for selected BMPs are presented in Table 4-1. Although these techniques were developed to reduce sediment production on agricultural fields, the same principles can be used by homeowners around the lake. Every effort should be made to reduce sediment inputs to both Cree and Schockopee Lakes. Contributions from residential areas and construction sites can be significant.

4.1.2 Nutrient Control Methods

Nutrient control strategies center on reducing the concentration of fertilizer and animal waste constituents in runoff. Techniques that focus on controlling sediment-bound forms of nitrogen and phosphorus generally also focus on controlling erosion/sedimentation and have been discussed in the previous section. The following paragraphs will also present measures for reducing the soluble fraction of these pollutants.

Two strategies for reducing potential nutrient enrichment of aquatic systems should be used in agricultural watersheds: (1) apply only enough fertilizer for use by crop or lawn plants, and (2) prevent excess nutrients from entering receiving waters. Because nutrients are available from many sources in addition to commercial fertilizer (e.g., animal waste, cut vegetation, crop residue), it is important to use both strategies in a complementary manner.

In order to apply enough fertilizer to support the crop or lawn plants without adding excessive amounts that will ultimately be transported by runoff, it is necessary to understand fertilizer uptake efficiency. Generally, uptake rates range between 50-70% but can be higher than 80% under good conditions (NCAES, 1982). In most cases, under-fertilization is much more noticeable in the short-term than is over-fertilization. The key incentive for a farmer or homeowner to understand uptake efficiency is reduction of costs associated with the purchase and application of commercial fertilizers. The following techniques can be used to increase the efficiency of fertilizer application and uptake.

Table 4-1. Cost estimates for selected erosion/sediment control strategies.[1]

Conservation Practice	Areal Units	Flat Rate Install. Costs $	Life-span Yrs.	Annual O&M % Costs	Annual Total Costs $
Conservation Planting					
Contour	Acre	10.00	10	5.00	2.23
Field	Acre	5.00	10	5.00	1.12
Wind-10 rod strips	Acre	4.00	10	5.00	0.89
11-20 rod strips		3.00	10	5.00	0.45
21-30 rod strips		2.00	10	5.00	0.45
Contour Farming	Acre	3.00	Annual	None	3.35
Critical Area Planting					
Shaping	Acre	200.00	25	3.00	30.62
Seed, Seeding Fertilizer, lime	Acre	220.00	25	3.00	33.68
Mulching (straw) (Anchored by treading)	Acre	425.00	1	0.00	473.88
Sodding	Sq. Yard	2.50	5	3.00	0.38
Pasture and Hayland Cover					
Tame species seeded with companion crop	Acre	130.00	15	3.00	22.48
Tame species with seedbed preparation	Acre	140.00	15	5.00	27.01
Native species with seedbed preparation	Acre	100.00	15	5.00	19.29
Interseeding with legume	Acre	85.00	6	5.00	24.63
Diversion (includes seeding/ mulching)	L. Feet	2.50	10	5.00	0.56
Grassed Waterway or Outlet (Includes seeding/mulching)	Acre	2000.00	10	3.00	406.75

[1]SCS estimates for state of Indiana (including interest payments @ 11.5%). All dollar amounts are subject to change based upon local conditions, material costs, and labor costs.

Table 4-1. Cost estimates for selected erosion/sediment control strategies[1] (Concluded).

Conservation Practice	Areal Units	Flat Rate Install. Costs $	Life-span Yrs.	Annual O&M % Costs	Annual Total Costs $
Grasses and Legumes in Rotation	Acre Considered as a production cost for crops.				
Sediment Basin	Cu Yard	1.25	25	5.00	0.22
Water & Sediment Control Basin	Cu Yard	2.00	15	5.00	0.39
Grade Stabilization Structure (4' Overfall)					
Rock Chute	Job Est.	1,500.00	25	3.00	229.65
Aluminum:					
<170 CFS	Job Est.	3,200.00	25	3.00	489.91
>170 CFS	Job Est.	4,800.00	25	3.00	734.87
Concrete Block Toewall	Job Est.	2,500.00	15	3.00	432.31
Reinforced Concrete	Job Est.	3,250.00	40	3.00	476.12
Wood	Job Est.	2,250.00	20	3.00	359.34
Concrete Block Chute	Job Est.	1,800.00	25	3.00	275.58
Grade Stabilization Structure (6' Overfall)					
Aluminum	Job Est.	8,000.00	25	3.00	1224.78
Wood	Job Est.	5,000.00	20	3.00	798.52
Reinforced Concrete	Job Est.	9,000.00	40	3.00	1318.48
Rock Chute	Job Est.	2,500.00	25	3.00	382.74
Concrete Block Chute	Job Est.	3,000.00	20	3.00	479.11
Mulching (Anchored by)					
Treading	Acre	300.00	2	None	8.19
Netting	Sq Yard	0.30	5	None	0.08
Asphalt Emulsion	Acre	400.00	5	None	109.59
Mulch Blankets	Sq Yard	1.00	2	1.00	0.60
Pasture and Hayland Management					
Pasture Continuous grazing	Acre	18.00	Annual	None	20.07
Rotation grazing	Acre	33.00	Annual	None	36.80
Terrace					
Gradient	L. Feet	1.50	20	2.00	0.22
Broadbased Parallel	L. Feet	2.75	15	2.00	0.45
Narrow Parallel	L. Feet	1.50	15	2.00	0.24
Grassed Back Slope	L. Feet	2.00	20	2.00	0.30
Riser Inlets	Each	50.00	20	5.00	8.99
Field Border/Filter Strips (1 rod wide)	1/2 mi	150.00	10	5.00	33.51

[1]SCS estimates for state of Indiana. All dollar amounts are subject to change based upon local conditions, material costs, and labor costs.

Soil Testing: Regular soil testing is an essential component of soil fertility management. Soil tests are used to estimate the quantity of available plant nutrients and to make recommendations about fertilizer and lime application. No commercial fertilizer should be applied without adequate testing of pre-existing soil conditions.

Liming: The pH of the soil is a key element influencing fertilizer utilization by crop and lawn plants. Soils that have a high organic content (e.g., mucks), high levels of exchangeable aluminum, or that have received heavy doses of ammonium fertilizers are often too acidic for efficient uptake of nutrients. Raising the pH to proper levels can optimize phosphate use, increase nitrogen fixation, reduce aluminum toxicity, control potash leaching, and mitigate micronutrient deficiencies.

Correct Timing: Timing of fertilizer application can be critical in determining the efficiency of nutrient uptake, crop yield, and lawn performance. Each plant species has a unique pattern of nutrient absorption and it is possible to maximize nutrient utilization by applying the fertilizer near the time of maximum growth. Crop type, date of planting, and soil conditions all affect the optimum timing of application. It is critical to tailor fertilization schedules to meet the demands of site-specific crops under site-specific conditions.

Correct Application Rate: It is important that neither nitrogen nor phosphorus be applied at rates higher than those derived from soil tests or other legitimate estimates. Fertilizers should be used only to provide nutrients not present in adequate amounts for optimum crop or grass production. Using too much fertilizer not only causes nonpoint source pollution, it also increases farm production costs, reducing farm profitability.

Correct Application Method: The method of application is important in determining the amount of nutrients exported from a field in runoff. Generally, broadcast fertilization is much more likely to result in nutrient contributions to runoff. Methods that either inject the fertilizer below the soil surface (e.g., knifing) or cover the fertilizer once it has been broadcast (e.g., disking) consistently reduce the amount of nutrients reaching surface waters. It is best to find methods that place the correct nutrient "dose" in the location where it will do the most good.

The second strategy for controlling nutrient runoff involves preventing the pollutants from reaching a water body. The following general recommendations for reducing the transport of phosphorus were adapted from NCAES (1982):

1. Contouring, terraces, sod-based rotations, and conservation tillage significantly reduce edge-of-field losses of particulate-bound phosphorus because they reduce erosion.

2. Sod-based rotations are particularly effective at reducing losses of soluble phosphorus.

3. Practices that involve residue management (e.g., no-till, minimum-till) have unpredictable results because vegetative residues can be a source of soluble nutrients while reducing erosion and particulate outputs.

4. Practices that do not involve residue management (e.g., terracing, contour farming) are moderately effective at reducing soluble phosphorus in runoff.

In situations where application rate, timing, and method are well-matched with crop requirements and appropriate field management, very small quantities of nutrients will be available to pollute receiving watersheds. All of the considerations listed above apply not only to farmers, but also to homeowners near the lakes and their tributaries.

Another important component of preventing nutrients from reaching surface water in agricultural and residential areas includes proper animal waste management. Factors that influence nutrient content of animal waste and its eventual availability to plants are: (1) method of waste collection; (2) length of time and the location where the waste is stored; (3) amount of feed, bedding, and/or water added to the waste; (4) timing and method of field application or ultimate disposal; (5) soil characteristics; and (6) climatic conditions. If the wastes are used as a fertilizer, then all of the considerations regarding soil testing, liming, timing, application rate, application method, and BMP selection should be employed to determine the application scenario that results in optimal plant production and minimal nonpoint source pollution. If the wastes are disposed without use as fertilizer, precautions should be taken to prevent contamination of runoff. Such precautions include proper disposal location, adequate vegetative cover between disposal area and surface water, and sufficient measures to restrict erosion of wastes during storm events.

4.1.3 Suggestions for Homeowners

The same principles of reducing sediment and nutrient inputs to surface water apply to both farmers and homeowners living in the Cree/Schockopee watershed. Residents living near the lakes or tributaries should ensure that lawn care and gardening practices do not create conditions that favor export of pollutants to the lakes. This section briefly outlines some suggestions for minimizing residential impacts on the water bodies. The Indiana Cooperative Extension Service should be able to provide more information upon request.

The following suggestions for lawn/garden care should be considered by all residents living in the watershed:

1. Avoid using fertilizers, herbicides, and pesticides unless persistent bare patches are present in the lawn. Residential lawn-care products are a major source of ground and surface water pollutants.

2. If fertilizers are required, test the soil to determine the amount of additional nutrients and/or liming needed. Add only the amounts of fertilizer/lime that

are indicated by the tests. Use well-directed application methods rather than broadcast techniques to ensure treatment of problem areas only.

3. Mow grass frequently to avoid scalping and thatch build-up. Cutting the grass too short destroys the food-making capability of the blades and increases lawn susceptibility to disease, drought, and weed infestation. Establish a schedule that ensures mowing will not cut off more than 1/3 of the grass blade at any one time.

4. Allow grass clippings to remain on the lawn unless excessive thatch build-up occurs (frequent mowing will prevent thatch). Ideally, grass should be allowed to compost on the lawn to provide nutrients without the use of commercial fertilizers. It has been estimated that leaving grass clippings on lawns will reduce the need for artificial nutrients by 20-30% the first year and by 35-40% each subsequent year (Hugo, 1990).

5. Do not bag clippings or leaves for disposal in a landfill. Nationwide, these materials constitute 15-20% of all substances placed in landfills. Grass thatch and raked leaves should be composted to provide nutrients for gardens and shrubs. Care should be exercised when establishing compost piles because they too can become a significant source of nutrients if adequate runoff protection (e.g., vegetative buffer strip) is not afforded.

Trash cans and dumpsters near the lake and tributaries should be emptied and cleaned on a routine basis. They should not be placed in areas that receive or influence runoff that reaches the lake. These containers should be covered so that rain water cannot enter. Drainage holes should not be drilled into the bottoms of such receptacles because water percolating through a trash can is high in both nutrient and bacterial content. Spillage should be avoided when emptying the receptacles and any stray materials should be retrieved and discarded properly.

The importance of domestic animal manure should be brought to the attention of homeowners in the residential areas near both lakes. Because pet droppings have been identified as a major source of nutrients and bacterial contamination in suburban areas, all homeowners should be encouraged to pick up pet wastes and dispose of them properly on a daily basis.

An excellent reference on actions that homeowners can take to control pollution is available from the Conservation Foundation and the National Audubon Society. This book, Controlling Nonpoint-Source Pollution: A Citizen's Handbook, by N. Hansen, H. Babcock, and E. Clark, can be purchased for approximately $15 by writing to:

The Conservation Foundation
1250 24th Street, NW
Washington, DC 20037

4.2 SEPTIC SYSTEM REMEDIES

Aging septic leach fields in muck and sandy soils appear to be a significant source of nutrients, especially to the canal system in Cree Lake. The problem may be summarized as being the result of septic systems that were installed in soils that have poor or unsuitable drainage and pollutant retention characteristics. It has been assumed that the replacing septic systems with connections to sanitary sewer system is economically infeasible because of the distance to the nearest existing sewage treatment plant (i.e., more than 6 miles) and the small number of households that would have to share the cost of constructing a new facility.

4.2.1 Improved Maintenance of Existing Systems

The simplest action that can be taken to reduce septic system nutrient inputs consists of improved maintenance of the existing systems. Basic maintenance normally includes having the septic tank pumped out annually. Unfortunately, it is not uncommon for homeowners to have their tanks pumped only when there is a very visible problem with the system. Prolonged intervals between pumping results in a decreased life expectancy for the system and increased nutrient loading to the drain field. Increasing the frequency of routine cleaning to every six months will help remove nutrients that would otherwise go out through the drain field and into the lake. The current cost of pumping in Noble County is approximately $50.

Every component of the septic system should be kept in optimum operating condition. Collapsed drain pipes, leaking tanks, and other signs of failure should be repaired immediately, and upgraded with new designs whenever possible. To determine whether there are any septic tanks that discharge directly to the lake, a dye testing program may be initiated in cooperation with the county health department. Be alert to the warning signs of failing systems which include sewage surfacing over the drainfield; lush, green growth over the drainfield; slowly draining toilets or drains; and sewage odors. Homeowners can also maintain their septic systems by practicing the following tips:

- Divert roof drains and surface water from driveways and hillsides away from the septic system (including the septic tank and the drain field).

- Take leftover hazardous household chemicals to approved hazardous waste collection centers for disposal. Do not pour poisons (i.e., gasoline, oil, paint thinner, pesticides, antifreeze) into drains because they kill the beneficial bacteria that treat wastewater in septic systems.

- The area over the drainfield should be left undisturbed with only a mowed grass cover.

- Do not use commercial septic tank additives as these products usually do not help and some may harm the system in the long run.

- Do not use the septic tank as a trash can by dumping nondegradables (i.e., grease, disposable diapers, plastics) down toilets or drains.

4.2.2 Replacement Systems

Given that most of the septic systems surrounding Cree and Schockopee Lakes are between 20 and 40 years old, and the fact that the Noble County Board of Health estimates a half-life of as little as 7.5 years for systems installed in muck soils, the replacement of failed systems in the near future should be considered inevitable. In all such cases, the first consideration should be given to replacement with improved designs that are better suited to local conditions.

As has been stated, the resident soils are poorly suited to use as septic drain fields. Therefore, the replacement of failed septic systems with waste treatment systems that do not use drain fields would be desirable. For example, holding tanks serving single homes or shared by a number of residences can be installed and pumped out by a septic maintenance service on a routine basis (e.g., monthly). The advantage of this type of system is that no pollutants are released to the surrounding environment and the collected waste is taken to a conventional sewage treatment plant for processing. The disadvantage is that operating costs are significantly higher than in traditional septic systems because a contractor must be engaged to pump out the tank regularly.

The use of conventional or modified septic systems with the most advanced design features may be appropriate on certain properties around lakes where conditions are such that the systems can be located to minimize the potential for contamination of the lake. Although the evaluation of specific site conditions and design alternatives is beyond the scope of this investigation, soil conditions and proximity to the lake and water table should be primary concerns in evaluating candidate sites. Perkins (1989), or a similar text, will provide a good reference for basic design considerations.

Price estimates for replacing a single-home septic tank (i.e., 1000 gallon tank) range from $2100 to $3000. Final costs depend on location, size of tank, and installation charges.

4.3 IN-LAKE SEDIMENT REMOVAL

The organic-rich sediment that has accumulated in the canal system of Cree Lake represents a significant problem, both as an impediment to boating and as a source of nutrients for plant growth. The removal of this sediment would provide an effective solution to both of these issues. Although the development of a sediment removal design project is beyond the scope of this investigation, some general comments will provide basic guidance. It must be noted that dredging will provide only short-term relief of eutrophic symptoms if land treatment measures (BMPs) are not established in the watershed and septic problems are not addressed to reduce future sediment and nutrient inputs.

To develop a preliminary estimate of the volume of material that would be removed during a dredging project, it was assumed that the organic sediments cover the bottom of the canals to a uniform depth of one foot. The surface area of the canal system is 14.3 acres. Based on these assumptions, there are approximately 23,000 cubic yards of poorly consolidated organic material in the canal system. This figure should be considered as the upper limit of the actual volume of material to be removed.

Sediment removal may be accomplished using a variety of dredging techniques, ranging from simple earth moving equipment to specialized suction dredges mounted on barges that use a pipeline to convey the dredge slurry to a dewatering and disposal site. Based on the size of the canals and the volume of material that is likely to be removed, the use of a bucket or a dragline dredge operated from the shore will probably prove to be the most economical method for cleaning out the canals of Cree Lake. Dump trucks may be used to transport the material off-site for disposal.

One of the most problematic aspects of any dredging project is disposal of the removed material. The sediment chemical analyses conducted during this project failed to reveal any contaminants that might prevent the safe disposal of dredged sediments. The most significant issue will be the identification of final dewatering and disposal sites for the material. The ideal location should be as close to the lake as possible, readily accessible to heavy truck traffic, and require a minimum of site preparation. Part of a dredge design project should include the identification and evaluation of candidate dredged material disposal areas.

Another potential problem with dredging is the possible detrimental effects on aquatic organisms and habitat. Dredging will undoubtably cause a major disruption of the sediments, causing particles to become suspended in the water column. Suspended sediment can be prevented from moving into the main water body through the use of sediment barriers. The disturbance in the canals during operations should be tolerated knowing that overall improvement will result.

Another issue to be considered before dredging is the potential impacts to sport fisheries in the lake. There is data to support the contention that the canal system holds a good percentage of adult spawning large mouth bass and provides suitable nursery areas for young-of-the-year bass (personal comm., Jed Pearson, IDNR). It is recommended that any dredging work be done after June to avoid disruption of spawning habitat.

With regard to the cost of canal dredging, sediment removal and disposal costs are typically in the range of $3.00 to $5.00 per cubic yard. Based on a total volume of 23,000 cubic yards, the total cost is likely to fall within the range of $70,000 to $120,000. Confident cost estimates should be developed during the dredge project design phase.

Dredging activities require a permit from the Corps of Engineers (Detroit District; telephone: 313-226-2218) as stipulated in Section 404 of the Federal Clean Water Act. An application must be submitted to the Corps whereupon receipt the request is evaluated. The Indiana Department of Environmental Management (IDEM) reviews all the Corps of Engineers' Section 404 dredge-and-fill applications as authorized by Section 401 of the Federal Clean Water Act. The Corps of Engineers cannot grant a Section 404 dredge-and-fill permit without first obtaining a water quality certification or waiver from IDEM (Office of Water Management; telephone: 317-243-5035). Indiana Department of Natural Resources (Division of Water; telephone: 317-232-4160) provides commentary on Section 401 waivers and requires an application for permit when construction activities are likely to occur in or immediately adjacent to a freshwater lake.

4.4 FUNDING SOURCES

The costs associated with the technologies discussed in preceding sections are frequently beyond the financial resources of small communities such as exist within the Cree Lake watershed. This is especially true of sewer system retrofits and large-scale dredging. There are some available mechanisms for small communities to obtain funding for these types of activities.

The most comprehensive source of information on waste treatment technology for small communities, including funding arrangements, is the National Small Flows Clearinghouse, funded by the U.S. Environmental Protection Agency (US EPA). A wide range of publications are available at little or no cost. Information may be obtained from:

The National Small Flows Clearinghouse
West Virginia University
P.O. Box 6064
Morgantown, WV 26506-6064

Unfortunately, the U.S. EPA recently ended its program providing grants to small communities for the construction of conventional sewerage treatment plants.

A source of funds for dredging projects may be available through the Indiana Lake Enhancement Program (LEP) in the form of grants to local organizations. However, in-lake measures will not be funded unless concurrent watershed treatment is being conducted. There are two steps to the process subsequent to a Feasibility Study: a Design Study to develop detailed engineering specifications and a Construction Project to implement the mitigative measures. Funding can be provided for both steps by LEP through grant application processes similar to that for LEP Feasibility Studies.

Funding for agricultural BMPs is available through cost-share provisions of the "T by 2000" cropland erosion control program sponsored by the Indiana Department of Natural Resources. Various Federal agencies (i.e., SCS and ASCS) also offer cost-share programs.

The U.S. Environmental Protection Agency funds a limited number of lake restoration projects through the Clean Lakes Program. The application process is similar to that required for LEP grants. Details can be obtained through the U.S. EPA Region VI office in Chicago, IL (telephone: 312-353-2000).

SECTION 5. SUMMARY AND RECOMMENDATIONS

This section presents a summary of the findings of this study. Principal recommendations are presented for the mitigation of the sediment and nutrient problems identified during the study.

5.1 SUMMARY

Based on the results of the watershed analyses, lake and tributary sampling, and visual observations, Cree and Schockopee Lakes appear to be adversely impacted in the following ways:

- The canal system in Cree Lake is experiencing advanced stages of eutrophication, reflected in the abundance of algae and macrophytes. The loss of depth in this area may be attributed largely to high levels of plant productivity that lead to increased sloughing and settling of biomass materials (i.e., algal cells and macrophyte tissue). The confined nature of the canals further exacerbates the problem because soluble plant nutrients are not readily mixed with the larger volumes of water available in the main body of the lake. Particulate plant nutrients entering the system via the small tributary leading from Schockopee are also trapped in the confinement.

- Primary sources of nutrients in the canal system include: (1) septic systems situated in the poorly drained soils along the canal shores; (2) recycling from the highly organic sediments on the canal bottom; (3) agricultural runoff entering the system through the tributary from Schockopee Lake; and (4) residential runoff from the lawns and gardens located along the system.

- The main body of Cree Lake appears to be relatively healthy in comparison with the canal system. The lake is, however, experiencing some problems with increased nutrient loading from septic systems and probably from lawn runoff along the shore. It appears that the canal system has protected the main body by acting as a sediment/nutrient trap, providing some measure of passive physical water treatment before pollutants enter the lake. If measures are not taken to restore the quality of the canals, it is anticipated that more pronounced effects will be observed in the lake as the resource degrades further.

- Schockopee Lake is influenced largely by runoff from the predominantly agricultural watershed. Large amounts of sediments and nutrients enter Schockopee via the tributary that empties into the southeastern end of the lake. In addition, the water body probably receives some nutrients from septic systems near the lake. Trophic conditions in Schockopee may be expected to deteriorate in the future under the current runoff loading conditions.

- Nutrient loading from the atmosphere may be significant in both lakes but management techniques are not readily available for reducing such input.

5.2 RECOMMENDATIONS

Approaches to restoring and protecting the quality of Cree and Schockopee Lakes should include both upland and in-lake measures. The installation of agricultural best management practices and septic tank maintenance should be given the highest priority as dredging activities will merely serve a as temporary solution. The recommended actions may be summarized as follows:

- The Cree Lake Association, and other residents in the watershed should become familiar with agricultural best management practices (BMPs) for controlling sediment and nutrient export to surface water bodies. The Cree Lake Association should work with the local SCS District Conservationist's office, the Noble County Soil and Water Conservation District, and the IDNR to encourage area farmers to install appropriate BMPs in locations deemed critical for preserving the quality of the lake resource. SCS is the agency that is responsible for coordinating the placement of BMPs with farmers and will provide free advice to landowners on appropriate strategies and designs. The IDNR can provide monetary assistance by way of the "T by 2000" cropland erosion control cost share program.

- Homeowners along the main body and canal system of Cree Lake should review alternatives to the current septic system arrangement. Given the prohibitive cost of constructing comprehensive waste water treatment facilities, replacement of septic systems with methods that do not use drain fields would be most desirable. A suggested option is the installation of holding tanks to serve one or more residences so that septic inputs can be pumped out and removed by a septic maintenance company on a routine basis (e.g., monthly).

- In order to restore the health of the resource and to preserve property values associated with the water body, the Cree Lake Association should initiate a design study for the removal of the organic sediments in the Cree Lake canal system. It is recommended that the canals be dredged down to the original hard bottom. A design study should furnish detailed engineering specifications, permit applications, and time tables for all on-site work to be done. The culmination of a design study is the preparation of bid-ready packages so that an appropriate contractor can be identified and hired via a cost-effective, competitive process.

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